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GROUNDING, BONDING AND SHIELDING BIBLIOGRAPHY 1930 TO 1971

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Final Report

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16. Abstract

As a result of a literature search carried out in conjunction with an extensive effort concerning grounding, bonding and shielding, a bibliography was compiled. The bibliography, covering the period 1930 to 1971, is contained in this report. A bibliography covering the period 1972 to the present will be published as a separate report.

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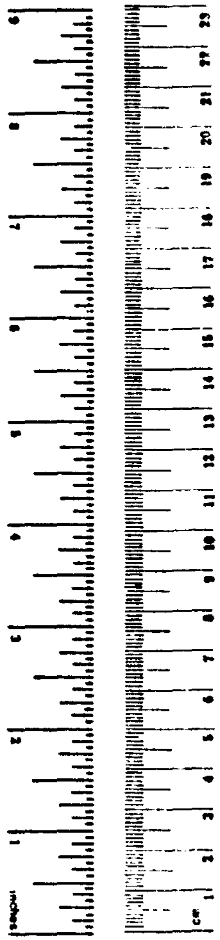
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

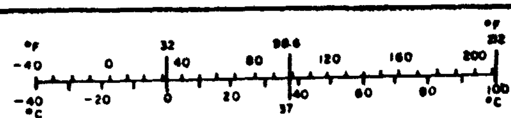
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Mutual Impedances of Ground-Return Circuits--Some Experimental Studies; A. E. Bowen, C. L. Gilkerson - AIEE Trans., Vol. 49, 1930, pp. 1370-1383.

This paper describes some of the results of the work of the Joint Development and Research Subcommittee of the National Electric Light Association and Bell Telephone System on the mutual impedances of ground-return circuits.

The first part of the paper deals with some experiments which were performed to establish an experimental background for the testing of theoretical ideas. Different theories, one involving an "equivalent ground-plane", a second d-c. distribution in the earth, and a third an a-c. distribution in the earth, are discussed in the light of the experimental results. While none of these is adequate to explain all the observed phenomena, each has a field in which it can be made useful.

The second part of the paper is devoted to a description of practical means for predetermining the mutual impedances of power and telephone lines. This involves an experimental determination of a curve of mutual impedance as a function of separation in the region of the proposed exposure and the calculation of the over-all mutual impedance between the proposed lines from this curve and the dimensions of the exposure. The results of trials of this method in two locations are given which indicate that it should be of sufficient accuracy for engineering purposes.

Voltages Induced by Arcing Grounds ; J. F. Peters, J. Slepian - AIEE Trans., Vol. 42, 1930, pp. 478-93.

The subject of arcing grounds in transmission systems is one of the greatest interest to operators of power systems of any extent. The almost universal grounding of the neutral in this country is done primarily to alleviate the destructive effects produced by arcing grounds. However, in spite of its great importance, a clear understanding of what happens in an arcing ground is not general. There is no agreement as to the magnitudes of voltages and surges produced, and the various theories proposed call for different properties of the arc. The authors therefore considered it well worth while to attempt in the laboratory to duplicate the conditions of an arcing ground on a transmission system and by spark gap determinations of voltages and by oscillograms to determine the maximum voltages developed and to discriminate between the various theories proposed.

Telephone Interference from A-C. Generators Feeding Directly on Line with Neutral Grounded; J. J. Smith, - AIEE Trans., Vol. 49, 1930, pp. 798-809.

The problem of telephone interference from a-c, generators feeding directly on the line with neutral grounded is discussed. It is shown that the triple and non-triple harmonics in the voltage wave shape cause currents which flow in different paths on the power system. As a result of this, the induction on paralleling telephone lines per ampere of triple harmonic is greater than the induction per ampere for a non-triple harmonic on a balanced power system.

A method of measurement which would allow a rough comparison of the effects to be expected from both types of harmonics is suggested. This is based upon using the apparatus already available and setting up special connections for test. Data are given showing the results of such measurements made in the factory on a number of machines while they were being tested.

Analyses are given of the wave shape of machines which gave rise to cases of interference. References are given to some of the data already published on methods which have been applied to relieve such situation.

An Investigation of Earthing Resistances; P. J. Higgs - AIEE, Vol. 68, pp. 736-750, 1363-1367, Feb. 1930.

Resistance of grounding electrodes is directly related to soil resistivity. This is a study of the relations between soil resistivity and moisture, temperature, and salinity. There is considerable disagreement in data on soil resistivity (Table 5) in this report as compared to Bureau of Standards data (Table I, J. P. Eaton's paper). Changes in resistivity with dc grounding are detailed.

The variation of resistivity with temperature and salt content are repeated in Eaton's paper.

The Calculation of Resistances to Ground and of Capacitance; H. B. Dwight - J. Math and Physics, Vol. 10, pp. 50-74, 1931.

Calculation of resistance to ground of various configurations of grounding conductors is essentially the same as the calculation of capacitance. Formulas are derived for: 1. Cylinder of finite length 2. Groups of vertical rods 3. Buried strip 4. Round plate 5. Rectangular plate.

Basic assumption - uniform ground resistivity.

Critique of Ground Wire Theory: L. V. Bewley - AIEE Trans., Vol. 55, pp. 1-22, Mar. 1936.

A tutorial on power line ground wires, including induced potentials, direct lightning hits, and other effects. Factors and effects considered include successive reflections, tower resistance, attenuation, telephone interference, zero phase sequence reactance, corona, and surge impedance.

The Resistance of Earth Electrodes: P. D. Morgan, H. G. Taylor - Proc. IEE, Vol. 72, 1932, pp. 515-18.

This paper, which is an abridgement of a report prepared by the E.R.A., deals briefly with the most important aspects of the resistance of electrodes used for earthing electrical installations and apparatus. After comparing the practice in various countries, details are given of the effect of the resistivity of the soil and the size and lay-out of electrodes on their resistance. It is shown that in order to have a low resistance the electrodes should cover a large area by consisting of either strips or, alternatively, a number of small electrodes connected in parallel. To facilitate the latter arrangement it is recommended that driven rod or pipe electrodes be used. A low resistance may also be obtained by salting the soil around electrodes, and this is considered together with the effect of using coke breeze.

Lightning Arrester Grounds: H. M. Towne - General Electric Review, Vol. 35, No. 3, Mar. 1932, pp. 173-77.

Characteristics of grounds, factors affecting their resistance, advantages of artificial treatment, maintenance and testing, general considerations with respect to various classes of electric circuits.

Lightning Arrester Grounds: H. M. Towne - General Electric Review, Vol. 35, No. 4, Apr. 1932, pp. 215-221.

Driving ground electrodes and making connections thereto, artificial treatment of soil energy dissipation in soil, impulse characteristics, resistance values.

Lightning Arrester Grounds: H. M. Towne - General Electric Review, Vol. 35, No. 5, May 1932, pp. 280-285.

Pole-type and station-type arrester grounds, common neutral ground wire, overcoming adverse conditions, railway and signal arrester grounds, inspection, measurements.

The Counterpoise; L. V. Bewley - G. E. Rev., Vol. 37, 1934, pp. 73-81.

The efficacy of a counterpoise in reducing lightning outages on transmission lines is generally recognized, but there has been considerable speculation as to just what factors contribute to this reduction. The object of this article is to analyze the several influences of the counterpoise and to evaluate their relative importance.

Three major effects are recognized in the action of a counterpoise.

Interference Prediction Study; Jansky, Bailey - Volumes I and II, Final Report, Jan. 1960, Contract no. AF 30 (602) - 1934, RADC TR-59-724.

Results of studies directed toward a solution of the interference prediction problem is presented. The report consists of chapters devoted to prediction techniques, generation of potential interference, transmission lines, antenna radiation characteristics, incidental interference, receivers and diversity consideratiosn. Propagation prediction methods are outlines in this report as they appear in the companion Volume II.

Measurement of the Resistance of Earth Electrodes; P. D. Morgan, H. G. Taylor - World Power, Vol. 21, 1934, pp. 22-6.

This report is the result of an extremely important investigation of methods of measurement of the resistance of earth electrodes of the types used in power systems. In this first instalment is given the general summary of the methods of measuring the resistance of earth electrodes, and a detailed analysis of methods using three current electrodes.

Measurement of the Resistance of Earth Electrodes; P. D. Morgan, H. G. Taylor - World Power, Vol. 21, 1934, pp. 76-81.

In this instalment, the authors deal with methods using two current and one potential electrodes. A comparison is made of measured resistance

with resistance to surges, and finally problems of over-head line tower resistance and soil resistivity are dealt with.

Theory and Tests of the Counterpoise; L. V. Bewley - Elec. Engng., Vol. 53, Aug. 1934, pp. 1163-72.

Different theories have been advanced as to the behavior of the counterpoise in the protection of power transmission lines against lightning. In an attempt to learn more about the counterpoise and to check the theories of its behavior, a series of basic field tests was conducted. The results of these tests, made on both the parallel insulated counterpoise and the buried counterpoise, are reported in this paper. The data obtained are analyzed, and conclusions are drawn.

The Electromagnetic Theory of Coaxial Transmission Lines and Cylindrical Shields; S. A. Schelkunoff - Bell System Tech. J., Vol. 13, Oct. 1934, pp. 532-79.

A form of circuit which is of considerable interest for the transmission of high frequency currents is one consisting of a cylindrical conducting tube within which a smaller conductor is coaxially placed. Such tubes have found appliation in radio stations to connect transmitting and receiving apparatus to antennae. As a part of the development work on such coaxial systems, it has been necessary to formulate the theory of transmission over a coaxial circuit and of the shielding against inductive effects which is afforded by the outer conductor. This paper deals generally with the transmission theory of coaxial circuits and extends the theory beyond the range of present application both as regards structure and frequency.

Interaction Between Radio Transmitting Stations (in close proximity): R. V. Lvovich - Izv. Elektroprom. Slab. Toka, No. 4, pp. 9-12, 1935.

Discusses the results of an investigation of the interaction of two transmitters, one operating at a wavelength of 47 m and one at a wavelength of 108 m. Voice and tone modulation was used in the experiment and strict precautions were used to prevent audio frequency coupling between the two transmitters. Concludes that the coupling was due to audio frequency conduction along the ground surface (rails, pipes, cables, etc.) which then entered the modulator grid circuit and was imposed on the carrier.

Radio in Aircraft; Shielding and Bonding Data; H. W. Roberts - Radio News, Jan., 1935.

Details shielding and bonding practices in aircraft in 1935.

The Phase and Magnitude of Earth Currents Near Radio Transmitting Antennas; George H. Brown - Proc. of Institute of Radio Engineers, Vol. 23, No. 2, pp. 168-82, Feb. 1935.

This paper deals with various electrical magnitudes involved in the process of radiation from an ordinary antenna. The calculations presented are based on the simplified assumptions of a highly conducting earth and a sinusoidal distribution of antenna current. Also, they neglect any components of the nearby field that may be associated with the flat top. The paper is divided into four main parts and an appendix. In the first part, the relative magnitudes and phases of earth currents associated with radiation from antennas of four representative proportions are calculated. In the second part, both the displacement current density and the electric intensity are studied quantitatively. The third part consists of an experimental verification of the calculated magnetic flux near the antenna. In the last section, the theory is applied to a simple half-wave antenna with a view to localizing the earth losses. These are found to be greatest at a distance from the base of the antenna of 0.35 . An appendix points out the magnitude of error in neglecting components of the nearby field associated with the flat top.

Earth Resistivity and Geological Structure; R. H. Card - Electrical Engrg., Nov. 1935, Vol. 54, pp. 1153-61.

The relation which the resistivity of the earth's crust bears to the geological structure has been studied with the aid of many experimentally obtained data. Although the resistivity is found to vary between wide limits, and not always to be the same even for the same types of rock formation in different locations, it has been found that the variation for any particular material is within more narrow limits, and that the older materials generally have the higher resistivities. The results of the studies are of value in several types of electrical calculations.

Currents and Potentials Along Leaky Ground-Return Conductors; E. D. Sunde - AIEE Trans., Vol. 55, 1936, pp. 1338-46.

The object of this paper is to derive general formulas for currents and potentials of a long, straight, uniform wire lying on the earth's surface but separated therefrom by a thin conducting shell and subject to an arbitrary impressed electromagnetic field varying with the time as exp; a general formula is also given for earth potential for these conditions. These results generalize the ordinary treatment of transmission effects in earth return conductors. By specializing the field, solutions are obtained for conditions basic to the application of the results to problems associated with electric railway systems, including propagation of track currents and voltages, earth potentials imposed on neighboring communication lines, currents and potentials of neighboring cables and other conductors, and electrolysis problems. By introducing approximations, the relation of the propagation constant ordinarily employed to the basic circuit and earth constants is disclosed.

<u>Calculation of Resistances to Ground</u>; H. B. Dwight - Elect. Engrg., Vol. 55, Dec., 1936, pp. 1319-1328.

A survey of formula for D-C resistance of various ground conductors, with deviations.

<u>Power System Faults to Ground</u>; C. L. Gilkeson, P. A. Jeanne, J. C. Davenport, Jr. - Elect. Engrg., Vol. 56, Apr. 1937, pp. 421-8.

The results of an extensive oscillographic study of power-system faults to ground are presented herewith. While this study was made primarily to obtain data useful in inductive co-ordination problems, the results are believed to be of general interest as well. They provide data on such items as frequency of occurrence of ground-current disturbances, their monthly distribution, duration, cause, method of clearance, and wave-trace characteristics. Data on fault resistance are given in a companion paper.

<u>Power System Faults to Ground</u>; C. L. Gilkeson, P. A. Jeanne, E. F. Vaage - Elect. Engrg., Vol. 56, Apr. 1937, pp. 428-33 and 474.

An allowance for fault resistance in fault current computations is desirable in certain types of problems. The present paper gives the results of a study made to determine reasonable values of fault resistance to use in computing line-to-ground fault currents, particularly in inductive coordination studies. The sources and nature of the data used in the study are described in a companion paper.

Ground Systems as a Factor in Antenna Efficiency; G. H. Brown, R. F. Lewis, J. Epstein - Proc. of Institute of Radio Engineers, Vol. 25, No. 6, pp. 753-87, June, 1937.

Theoretical considerations concerning the losses in ground systems are advanced. These considerations indicate the feasibility of antennas much less than a quarter wave length tall, for low power broadcast use. The desirability of large ground systems is also indicated.

Experimental data are given which show that an eighth-wave antenna is practically as efficient as a quarter-wave antenna. It is also found that a ground system consisting of 120 buried radial wires, each one-half wave long, is desirable. Tests of ground screens show them to be of no importance when adequate ground systems are used.

The experimental data include antenna resistance and reactance, field intensity at one mile, current in the buried wires, and total earth currents, for many combinations of antenna height, number of radial wires, and length of radial wires.

Radial Ground System Chart; George H. Brown - Electronics Magazine, January, 1938.

This is an "Electronics Reference Sheet" showing signal strength in millivolts per meter at one mile from a vertical antenna using a radial-wire ground system and antenna-input power of 1000 watts. Three families of curves are given, each for a different number of radial wires (30, 60 and 120). The graphs plot antenna heights, radial length, wave length, number of radials and resulting field strength.

Determination Of Ground-fault Current and Voltages on Transmission Systems; E. M. Hunter, F. Pragst, P. H. Light - G. E. Review, Vol. 42, No. 8, Aug. 1939.

Fundamental frequency line to ground voltages during ground faults.

Determination of Ground-fault Current and Voltages on Transmission Systems; E. M. Hunter, E. Pragst, P. H. Light - G. E. Review, Vol. 42, No. 11, Nov. 1939.

Transmission System restored voltages and short circuit current for double line to ground faults.

Practical Aspects of Earthing; F. Fawssett, H. W. Grimmitt, G. F. Shotter, H. G. Taylor - Proc. IEE, Vol. 87, 1940, pp. 357-400.

Earthing is first considered in relation to the various regulations applicable in Great Britain. These regulations relate to the generation, transmission and use of electricity, and the last item covers use in all types of consumers' premises. Particular attention is given throughout the paper to the peculiar difficulties attendant upon supply in rural areas, where protection is difficult to obtain. The factors affecting the resistance of earth electrodes are their size and shape, and the resistivity of the soil. All these items are dealt with in detail, including an analysis of the effect of rainfall on electrodes, both with and without artificial treatment. This analysis is based on the results of E.R.A. tests which have been in progress for 7 years. Only brief reference is made to the means of avoiding voltage gradients around earth electrodes which are dangerous to cattle, since this has been fully considered elsewhere. Current loading capacity is treated somewhat more fully in view of the important nature of the work and the fact that this is the first occasion on which any such results have been made public. The paper concludes with a section on the design of earth electrodes in which an attempt is made to correlate all the essential features bearing on electrodes, to show them in their true perspective in relation to the whole problem of earthing, and to relate the whole to practical requirements in which the question of cost plays a very important part.

Sensitive Ground Protection for Radial Distribution Feeders; Lloyd F. Hunt, J. H. Vivian - AIEE Trans., Vol. 59, 1940, pp. 84-90.

There are three reasons for isolating or de-energizing grounded feeders: first, danger to life; second, danger to property, and third, to permit joint use of pole lines with the telephone companies. The first two are very difficult to evaluate, but in certain territories a means of isolation is very important. The third reason can be given a definite value, and the economies resulting from joint use of pole lines can more than justify this proposed scheme of sensitive ground protection for radial feeders.

This paper will not discuss the merits of leaving a ground-faulted feeder in service for the continuity of service, as may be the practice by some utilities, but discusses the methods of clearing ground faults that may normally occur on radial feeders.

Charts Show Ground Rod Depth for Any Resistance-In Advance; R. M. Schahfer, W. H. Knutz - Electrical World, Vol. 114, Oct. 19, 1940, pp. 63-5

Three year ground study establishes empirical relation between ground rod depth and ground resistance for single rods and groups in parallel - permits accurate material estimates on grounding projects in advance of construction.

Shielding of Transmission Lines; C. F. Wagner, G. D. McCann, G. L. Mac Lane, Jr. - AIEE Trans., Vol. 60, pp. 313-328, 614, 1941.

Historical data and laboratory modeling are used to determine the optimum positioning of ground wires to protect power lines against lightning.

Impulse and 60-cycle Characteristics of Driven Grounds; P. L. Bellasohi - AIEE Trans., Vol. 60., pp. 123-128, 717-719, Mar. 1941.

A high voltage impulse generator, grounded with a 0.9 laboratory quality earthing arrangement, pulsed various arrangements of four driven ground rods. A cathode ray oscilloscope, a voltmeter/ammeter combination, and a Biddle megger measured the impulse, 60 Hz and megger resistance of the driven ground rods.

The impulse resistance was found to be less than 60 Hz resistance, and the ratio of impulse resistance to 60 Hz resistance decreased with impulse (crest) current. Icing weather increased both 60 Hz and impulse resistance.

Grounding Electric Circuits Effectively; J. K. Eaton - G. E. Rev. Vol. 44, pp. 323-327, 397-404, 451-456, June, July, Aug. 1941.

A basic approach to the design of systems which connect equipment, structures, etc., to the earth. A set of general conclusions of grounding system effectiveness, as a function of a number of parameters, is presented. Parameters include soil resistivity dimensions and number of ground rods, type of ground electrode and potential gradients in the system. Approximate formulae are given for various electrode configurations. Installation methods are suggested, and methods of measuring ground resistance (at low frequencies) are presented.

Sensitive Ground Protection for Transmission Lines and Distribution Feeders; Eric T. B. Gross - AIEE Trans., Vol. 60, Nov. 1941, pp. 968-71.

If ground fault coils are used in high tension overhead systems and underground cable networks, earth leakage relays may be employed to indicate the location of singel ground faults. The influence of the contact resistance at the point of the ground is explained. Earth leakage relays in compensated networks, their operation in radial and meshed networks, and the means for determining their correct operation by tests, are described. The paper is based on the practical experiences gained from such installations in England and in Continental Europe.

Lightning Arrestor Application and System Overvoltage; H. A. Peterson, E. M. Hunter - Electric Light and Power, Vol. 19, Nov. 1941, pp. 60-64, 66.

For guidance in lightning arrestor applications and system operation, the authors have classified transmission and distribution system overvoltages other than those caused by lightning and made a comparison of overvoltage magnitudes obtained with various methods of neutral grounding.

Criteria for Neutral Stability of Wye-Grounded-Primary - Delta-Secondary Transformer Circuits; H. I. Shott and H. A. Petersen - AIEE Trans., Vol. 60, pp. 997-1002, 1394-1395, Nov. 1941.

The transformer circuits analyzed are potential transformer arrangements used to detect faults in 3-phase power systems which have ungrounded neutrals. It is shown that certain system conditions cause instability in the fault detection circuits (which may be used for metering or for relay control). Methods of controlling the instabilities are outlined.

Shielding of Substation; C. F. Wagner, G. D. McCann, A. M. Lear - AIEE Trans., Vol. 61, pp. 96-99, Feb., 1942.

Data is presented on the probability of lightning strikes on substations and on the protection of areas by masts. Effects of earth resistivity are included.

Junctions in Aluminium Cable; Light Metals, Vol. 5, Oct. 1942, pp. 388-95.

One of the main problems in the use of aluminium electrical wiring and conducting systems of all types is the provision of suitable joining and

terminal devices. Fault practice in the application of these elements is capable of leading to endless trouble. In the electric industry particularly, problems of this type cannot be solved on the drawing board and close observations of practice employed in the laboratory would seem to be the best approach.

For cable work, joining by welding has hitherto proved to be the most satisfactory, and this sytem has been widely employed. It is stated also in the literature that soldering is used, but the reviewer has so far been unable to trace an example of this practice. He would, indeed, be most interested to learn in what connection it is used.

Mechanical joining devices, however, for all their disadvantages from the standpoint of electrical science, possess the supreme merits of simplicity, rapidity and cheapness. Furthermore, they may be applied in situations where the use of welding is accompanied by some hazard. They do not demand the services of skilled men and may be employed and fitted in situ into spaces quite precluding the use of any other methods.

The reliability and usefulness of mechanical connections is, as we have inferred, still open to some doubt in certain quarters. The investigations summarized in the following report embrace small cable connectors up to 16 sq. mm. cross-section, medium cables of approximately 35 sq mm. cross-section and large cables of 95 sq mm cross-section bus bar connections are also dealt with.

<u>The Effect of Corona on Coupling Factors Between Ground Wires and Phase Conductors</u>; G. D. McCann - AIEE Trans., Vol. 62, 1943, pp. 818-26, 941.2

Measurements of coupling factors between ground wires and phase conductors, as a function of ground-wire voltage, have been made for a sufficient number of cases to determine them for any of the standard transmission-line configurations. It was found that the effect of corona can be expressed in terms of an effective corona ground-wire radius to be used in the conventional coupling-factor equations. Curves are also presented for the quick determination of coupling factors for all standard line configurations. A photographic study of the visual characteristics of surge corona was made for a comparison with the effective radius and with 60-cycle corona.

Actual measurements were made for potentials up to about 2,000 kv, but the data were extrapolated to 6,000 kv with what is considered to be reasonably good accuracy. Coupling factors for positive polarity were found to be considerably higher than those for negative polarity and both higher than values previously calculated from purely theoretical considerations. For a potential of 1,000 kv the actual coupling is 1.2 to 1.5 and 1.4 to 1.8 times as great, for negative and positive polarity respectively, as the values obtained by assuming no corona. At 2,000 kv

the corresponding figures are 1.4 to 2 and 1.6 to 2.7 respectively, and at 4,000 kv 1.7 to 2.9 and 2 to 4.

Ground-wire size was found to be unimportant above about 200 kv and, therefore, need not be considered. Coupling factors measured below the critical corona voltage-checked calculations that assumed the actual earth's surface to be the effective ground plane. These measurements were made over soil whose resistivity was as high as 600 meter ohms. It is thought that the actual surface should apply for such electrostatic phenomena except for very high values of earth resistivity.

Measurements were also made of the critical flashover of rod gaps connected between the ground wire and floating phase conductor. The critical breakdown values of such gaps under these conditions were found over the range of voltages studied, to be essentially the same as with the conductor grounded. These data also showed that, at heights of 30 feet or more above the earth, the influence of the earth plane is neglible. For symmetrical gap electrodes, breakdown is independent of polarity and close to the positive polarity breakdown of standard rod gaps.

A configuration consisting of a third ground wire placed below the phase conductors for increased coupling was also studied. Although the coupling for all measured voltages was greater than without the third ground wire, it did not increase as rapidly with voltage as calculations assuming the effective corona radii found for only one or two ground wires would indicate. This was thought to be due to mutual shielding produced by the ground wires tending to decrease corona streamers in the space between them.

How to Apply Neutral Grounding Devices; A. A. Johnson - Westinghouse Engineering, pp. 66-69, May, 1943.

This paper indicates how neutrals can be grounded, through proper network devices. Reactor and resistor grounding requirements and grounding through a small power transformer are analyzed.

System Electrical Neutral Grounding; W. K. Boice, E. M. Hunter - Electric Light & Power, Vol. 21, Nov. 1943, pp. 44-9.

Basic considerations of grounding are set forth and types of grounding equipment, such as grounding transformers, grounding resistors, reactors, and ground-fault neutralizers are discussed. Application guides for system grounding are given.

Lightning Protection for Rotating Machines; G. D. McCann, E. Beck, L. A. Finzi - AIEE Trans., Vol. 63, 1944, pp. 319-332, 488-489.

The high monetary value and low insulation levels of rotating machines make it necessary to employ special protection. A rotating machine can be conceived as a transmission line with distributed constants, the essential difference being that the machine winding is wound back on itself in the form of turns, which may permit high voltage across the turn-to-turn insulation. The installation of special arresters with low and consistent spark-over characteristics will limit satisfactorily the maximum voltage that can appear across the terminals. However, capacitors also are requried which, in conjunction with the inductance in the line, slope the front of the wave and thus prevent piling up of voltage across the turns. Present methods of protection, on the whole have proved quite satisfactory. However, in view of the statistical data that have been accumulated in extensive lightning investigations, the recognition of the importance of providing good grounding for the line arresters, and the appreciation of the value of the inherently low discharge voltage characteristics of the deion arrester, it has been considered desriable to study this problem further.

The more important results of this study are summarized here with the viewpoint of providing a simple and straightforward basis for machine protection which affords the increased protection and saving in installation cost and material that it was found possible to achieve. Although the protection required at the machine and in the line are mutually interdependent, it is possible to resolve the suggestions for protection into the four following categories:

A. Protection at the machine terminal or bus. B. Line protection for machines connected directly to overhead lines. C. Line protection for machines connected to overhead lines through cables. D. Protection of machines connected to lines through transformers.

The Functions of Ground Reference in Carrier-Current Relay Schemes; D. C. Leyland, F. L. Goldsborough - AIEE Trans. Vol. 63, pp. 97-100, 437, Mar. 1944.

Common practice in carrier relay protection systems is to design for ground current faults to take preference over phase faults. Sometimes this logic is not best. A combination of distance and direction control of relay protection is described.

Report of Conference on R-F Cables; J. H. Nebeer - AIEE Trans., Vol. 64, pp. 911-941, 1945.

A post World War II report on solid dielectric coaxial cable developed by the "Army Navy Radio-Frequency Cable Co-ordinating Group, TAN-C-17 was generated. Four papers in the conference report detail the properties of polyethylene solid dielectric. Paper No. VII describes manufacturing techniques. No. VIII concerns itself with design problems. Papers No. VIII through XII detail design considerations concerning losses power ratings, shielding, specifications, and twin conductor (triax and twin lead) cables. Papers No. XIII through XVII describe test methodology.

Grounding Principles and Practice I-Fundamental Considerations on Ground Currents; Reinhold Rudenberg - Electrical Engineering, Vol. 64, No. 1, Jan. 1945, pp. 1-13.

The behavior of currents flowing in the earth, as influenced by the resistivity of the soil, frequency of the current, and size and shape of electrodes, is analyzed here.

Grounding Principles and Practices II-Establishing Grounds; Claude Jensen - Electrical Engrg., Vol. 64, No. 2, Feb. 1945, pp. 68-74.

Various types of ground connections, together with methods for measuring ground resistance, are discussed.

Shielding of Dielectric Heating Installtion; G. W. Klingaman, G. H. Williams - Electronics, pp. 106-109, May, 1945.

Dielectric heating equipment (9MHz) radiates considerable RF energy, at its fundamental frequency and at harmonics. The radiation measured at 1000 feet from one installation was 45dB above 20mv/meter, the ambient industrial noise level. The first harmonic was 26 dB below the fundamental, the fifth harmonic was 35 dB below the fundamental.

A step-by-step construction of a screen cage, sealing of the equipment housing and line filtering measures taken, are described.

Distribution Transformer Neutral Grounding; R. F. Quinn - G. E. Review, pp. 34-37, June, 1945.

An explanation is given for not grounding or connecting to the high-voltage line neutrals the high voltage neutral of Y - transformer

banks. (Of course, connection through a proper impedance is permissible.).

Semiconducting Shielding for A-C Power Cable; Edwin J. Merrell - AIEE Trans., Vol. 65, pp. 605-609, 1148,1946.

Charing of 60 Hz, A-C, power cable is reduced through the use of resistive shielding . Factors considered in designing for the use of resistance shielding include: maximum spacing between ground points, line voltage, and cable diameter.

Effectiveness of Conduit as R-F Shielding; Scott R. Shive - Electronics, Vol. 19, pp. 160-166, Feb. 1946.

Laboratory evaluation of conduit shielding effectiveness. Solid-wall tubing and braid shielding were measured, up to 150 MHz.

Operating Experience with Distance Ground Relays; W. A. Wolfe - AIEE Trans., Vol. 65, pp. 458-462, 1186-7, Jully, 1946.

Relays which can detect distance to fault and only trip to protect adjacent lines sections, are described.

Shielding High-Frequency Circuits can be Effective Engineered; Electrical Manufacturin, pp. 134-137, Sept., 1946.

Do and don't article on shielding and line-filtering industrial R-F generators.

Sensitive Ground Relay Protection for Complex Distribution Circuits; Lloyd F. Hunt - AIEE Trans., Vol. 65, pp. 765-767, Nov. 1946.

On the order of 1% of rated current, e.g. 2 amps of ground current for a 200 amp/5 amp current transformer, will be sufficient to trip protection relays, in a properly designed system for lower voltage distribution.

Relays used detect the direction of fault current flow, and by proper interconnection can discriminate ground fault versus phase-to-phase fault, and initiate appropriate disconnects.

Grounding of Instrument Transformer Secondary Circuits; AIEE Committee Report - AIEE Trans., Vol. 66, pp. 419-420, 1947.

AIEE relay subcommittee recommends preferred practice on grounding of instrument transformer secondary.

1. Grounding is necessary for safety of personnel and equipment. Cases should be grounded. 2. Do not use "station ground copper" for instrument transformer ground. 3. Single point grounding precludes fault current in transformer secondary circuit. 4. Grounding at the switchboard was favored over grounding at instrument transformer terminals. 5. Secondary circuits should be checked periodically for shorts, opens, accidental grounds, insulation.

Present-Day Grounding Practices on Power Systems; AIEE Committee Report - AIEE Trans., Vol. 66, 1947, pp. 1525-51.

The AIEE subject committee on present-day grounding practices has prepared this report on the grounding practices of power systems from replies to questionnaires submitted to those electrical utilities, both public and private, in the United States and Canada, having a generating capacity of more than 10,000 kw or having more than 10,000 customers.

The report covers separately grounding practices on generating stations and on transmission and distribution systems. The scope of this survey is indicated by:

Generating stations: 460 systems operating at 11 kv and above. 33,752 megavolt-amperes in generating capacity. 972 generating units.

Transmission and distribution systems: 567 systems operating at 22 kv and above. 119,081 miles of transmission and distribution circuits.

These figures indicate that information was obtained on about three fourths of the facilities in the classes investigated.

Grounding methods are classified for generating stations according to the station layout, and for transmission and distribution systems according to the voltage class. Data are given as to size and number of systems, the ratio of phase-to-ground to 3-phase fault currents, and the sequence-impedance ratios. The principal characteristics of the grounding devices themselves are tabulated. The opinions of the utilities as to the importance of 16 different factors in the grounding problem as applied to their particular systems, as well as the assigned reasons for their specific practice, have been included. A particularly valuable part of the report reviews operating experiences including unsatisfactory operation, occurrence of double faults, and changes that have been made, are being made, or are contemplated. Trends in system

grounding are discussed from current data and information from previous reports.

The body of this report is arranged in two parts: generating stations and transmission and distribution systems. An appendix provides a list of utilities that supplied data.

Thorough Grounding Pays Dividends in Service ; R. C. Stevenson, Jr., - Electrical World, Jan. 1947, pp. 48-50.

In a typical area on the Chattanooga power systems, nine out of ten grounds were found insufficiently conductive. This paper describes the methods of improvement in grounds which resulted in one-third the distribution transformer interruptions and less customer calls.

Radio Interference from Industrial R.F. Heating Equipment; A. Turney - Electronic Engrg., Vol. 19, Aug. 1947, pp. 251-5, 264.

Considerable information has been obtained relating to the reduction of interference from electric motors and the like in which radio frequency fields are produced as a by-product of the normal operation of the equipment and are essential to its proper function. This information has been embodied in various standards and codes of practice. The increasing use of radio frequency power for industrial and medical purposes stresses the need for similar consideration of the class of equipments in which the production of large radio frequency fields is essential to their operation.

At present, little is known of the degree of interference caused, and no information is available regarding the nature of the stray fields from such equipment. However, some preliminary work has been carried out involving field strength surveys in the neighborhood of R.F. heating equipment, measurement of R.F. voltage on the power supply mains, and in one case a determination of the effect of load heating on the operating frequency. The results of these measurements are described below, and it is hoped that they will serve to indicate the magnitude of the problem and give some idea of the effectiveness of the suppression already used. These tests have been, so far, of a limited character, but it is felt that the lower powered equipment, i.e., up to about 5 KW, which has been given the most consideration, will be the largest potential source of interference. Such equipment is usually transportable, and any screening of other method of suppression must be integral with the equipment. Higher powered equipments are more likely to be erected on site and built into screened rooms which can be arranged to provide the degree of suppression required in the particular case.

Aluminum Busbar Laps & Joints Need Not be Larger than Copper; S. C. Killian - Electrical World, Vol. 128, Sept. 13, 1947, pp. 118-9.

This article proves false the commonly accepted statement "aluminum must have twice the contact area." Also confuted is the conception of necessary al.-to-cu. contact area.

Shielding Industrial Electronic Generators; R. A. Whiteman - Radio News Engineering Edition, Vol. 39, pp. 8-10, 25, Sept. 1947.

For industrial RF generators, FCC has assigned a number of frequencies and specified limits on frequency tolerance. If the generators do not conform to the FCC specs, they must be shielded and their power lines must be filtered. The paper presents curves on depth of penetration in aluminum, copper, and iron, versus frequency; attenuation of 13 MHz of copper and aluminum screen; the FCC specs; and a design for a power line filter.

Locates Grounds in Shielded Room; Electronics, Vol. 20, pp. 134, 148, 150, Oct., 1947.

Technique is described for probing for a fault or ground between inner and outer screens of a shielded room. About 100 ampers of 60 Hz current was caused to flow between screens, and a solenoid search coil was hand scanned across the room walls, until an oscilloscope showed reversal of coil current.

An Experimental Investigation of the Electrical Performance of Bolted Aluminum-to-Copper Connections; W. F. Bonwitt - AIEE Trans., Vol. 67, 1948, pp. 1208-19.

Bolted bus connections between bare aluminum and copper, with an electro-tinned and flowed finish, will provide a low-resistance joint which will be reasonably stable even under extreme conditions of elevated temperature and corrosive attack. While the use of a compound, Penetrox "A", will greatly improve and stabilize the contact conditions, the combination of aluminum and copper (electrotinned and flowed) will form a satisfactory electric connection even when made without the use of any compound.

Comparative Properties of Grounding Electrodes; Electrical World, Engrg., Reference Sheet No. 48-5, V31, Jan. 1948, P. 72, Vol. 129.

Data provide a comparison of various types of ground electrodes w.r.t. electrical, geometrical, and thermal qualities during operation.

Earthing Problems; R. W. Ryder - Proc. IEE, Vol. 95, Apr. 1948, pp. 175-84.

The paper discusses the various factors which affect the resistance of earth electrodes and contains a summary of the different types of electrodes in common use for obtaining an earth connection. Special reference is made to the use of deep-driven rods and the results obtained by the author using these electrodes in various parts of the country.

A short description is given of existing earthing practice on high-voltage apparatus, while the methods available for providing efficient protection on low-voltage apparatus are discussed in detail.

The concluding Sections deal with the need for periodic testing of existing installations and the methods to be employed in carrying out such tests, with a final plea to those in authority to give a lead in a more rational approach to this most important subject.

Report on Survey of Unbalanced Changing Currents on Transmission Lines as Affecting GroundFault Neutralizer; AIEE Committee - AIEE Trans., Vol. 68, pp. 1328-29, 1949.

The background for the recommendations in Standard Number 32 concerned with the continuous current rating of ground fault neutralizers.

Automatic Grounding and Air-Break Switches for Protection of Transformer Stations; E. A. Ricker - AIEE Trans., Vol. 68, pp. 851-857, 1949.

Describes a combination of an automatic grounding switch and an automatic opening air-break switch to replace a 110 KV circuit breaker.

Radio Influence from High-Voltage Corona ; Gordon R. Slemon - AIEE Trans., Vol. 68, pt. 1, 1949, pp. 198-205.

In the study of high-voltage power transmission, corona phenomena have received considerable attention. The power loss which accompanies corona has been investigated to the extent that general prediction may

be made under most conditions. The increase in the voltage level of long-distance transmission lines, coupled with the extension of communication facilities, has created a demand for a more adequate knowledge of the radio-frequency propagation which may be expected from corona.

The experimental work of this project has been directed toward two main objectives. The first of these is a clarification and extension of the basic concepts of the space-charge phenomena which occur in corona. The general conditions under which radiating impulse currents will occur have been described, and an attempt has been made to show the effects of some of the variable factors. From the observations, certain additions and clarification have been made in corona theory. With the aid of this firmer theoretical background, a beginning has been made in the field of radio interference control under various voltage conditions.

Operation of a Ground-fault Neutralizer; H. R. Temlinson, F. B. Hurt - AIEE Trans., Vol. 68, pp. 1321-1327, 1949.

A Bausch transformer resonant neutral grounding scheme (as opposed to Peterson coil single phase grounding) is described for a delta-connected system.

Thermal Contact Resistance of Laminated and Machined Joints; A. W. Brunot, F. F. Buckland - Amer. Society of Mechanical Engrs. Trans., Vol. 71, Apr. 1949.

Values of thermal contact resistance are reported for two types of joints: (1) the joint between two blocks of laminated steel, either in direct contact or separated by cement or shims of steel, aluminum, or aluminum foil; (2) the joint between two blocks of cold-rolled steel with various surface finishes. The resistance as measured amounts to 0.3 to 8 in. of additional material, depending upon the configuration. Results are also given in terms of contact resistance.

Thermal Resistance Measurements of Joints Formed Between Stationary Metal Surfaces; N. D. Weills, E. A. Ryder - Trans. American Society of Mechanical Engrs., Vol. 71, Apr. 1949, pp. 159-67.

Results are presented of the measurements of the thermal resistance of dry and oil-filled joints formed between two flat surface of various metals. Experimental apparatus consisted of two test blocks, 3 in. diam x 3 in. long, stacked axially on one another, in contact with an inductively heated copper block at one end and with a water-cooled

copper block at the other, all placed between the platens of a hydraulic press. The termal conductance of the joint formed between the two test blocks was obtained from the measured heat flow and temperature gradient through the blocks and studied as a function of temperature, pressure, and surface finish. The temperature at the joint ranged from 300 to 500° F, the thermal current across the joint from 10,000 to 130,000 Btu/(hr) (sq ft), the temperature drop across the joint from 1 to 100° F, and the pressure on the joint from 2 to 8000 psi. The thermal resistance, interpreted by analogy to the concept of electrical spreading resistance, is decreased by increasing the temperature and pressure, by the inclusion of oil, or by plating the surfaces with a soft metal.

Sensitive Ground Protection: AIEE Committee Report - AIEE Trans., Vol. 69, 1950, pp. 473-6.

The Project Committee has collected information on available methods for sensitive ground relaying of a 3-phase distribution and transmission circuits and unigrounded as well as ungrounded distribution systems have been reviewed. The limitations of presently known systems for the protection of 3-phase 4-wire multigrounded systems, as well as some results of investigations concerning "are frequency relaying" which need further experimental study, are indicated.

In the Fall of 1946, a working group was appointed to study present-day sensitive ground protection of 3-phase systems and to prepare a report on this subject. It was realized that the project Committee would not be able to find new solutions to some of the problems, but it was felt that it would be helpful to summarize present-day practices and to give an indication where developments and improvements are necessary or desirable. A number of papers which concern certain phases of sensitive ground protection have been published during the last ten years, and they are given in the list of references, which describe in detail some of the fine points not repeated in this report.

Practical Experience with Resonant Grounding in a Large 34.5-KV System; Harold H. Brenen, Eric T. B. Gross - AIEE Trans., Vol. 69, pp. 1401-1406, 1950.

Installation of resonant neutral grounding on a large 34.5KV system, which had been ungrounded produced the predicted improvement.

Development of the Standard for Neutral Grounding Devices; J. E. Clem - AIEE Trans., Vol. 69, pp. 976-979, 1950.

Relates how AIEE Standard Number 32, Neutral Grounding Devices, June, 1942, was written.

A New Grounding and Testing Device for Metal-Clad Switchgear; H. Krida, E. T. Mc Curry - AIEE Trans., Vol. 69, pp. 407-415, 1950.

Mechanical design details of a glow tube voltage indicator for 4 to 14 KV power circuits. It permits: checking presence (or absence) of voltage in either bus or line, phase sequence, insulation resistance, fault resistance device connection, crowbarring bus or line conductors to ground.

Protective Grounding of Electrical Installations on Customer's Premises; A. H. Schirmer - AIEE Trans., Vol. 69, 1950, pp. 657-9.

The problem of electrical safety in rural areas is one of providing adequate insulation on circuits and equipment, and effective grounding and bonding. Providing adequate insulation presents no particular problems. However, there is some confusion as to what constitutes effective grounding and bonding. This paper briefly discusses the various factors which must be taken into account. The discussion is limited to a-c circuits.

Neutral Grounding Methods for Industrial Power Systems; W. F. Strong - Industry and Power, Vol. 58, Pt. 1 - No. 2, Feb. 1950, pp. 90-2.

This article gives consideration to some of the factors that are important in the application of neutral grounding techniques; also it indicates the methods preferred for different systems. Discussion is limited to industrial systems and voltage levels of 120 volts to 13.8 kv.

Neutral Grounding Methods for Industrial Power Systems; W. F. Strong - Industry and Power, Vol. 58, Pt. 2 - No. 3, Mar. 1950, pp. 80-2.

In this second article of his series on neutral grounding of industrial power systems, the author continues his description of grounding methods for medium and low voltage systems and discusses in addition the selection of resistors, as well as the grounding of portable electrical units.

Neutral Grounding Methods for Industrial Power Systems; W. F. Strong - Industry and Power, Vol. 58, Pt. 3 - No. 4, Apr. 1950, pp. 76-8.

The third and last article in a series on neutral grounding of industrial power system is composed of highly practical and useful application rules, well illustrated by easily understood diagrams.

Screening; Wireless World, Vol. 56, pp. 211-214, June, 1950.

Layman presentation of magnetic and electrical shielding requirements.

Transmission and Distribution Grounding in the Hydro-Electric Power Commission of Ontario; W. W. Loucks, W. A. R. Lemire - AIEE Trans., Vol. 70, pt. 2, 1951, pp. 1493-9.

Accepted grounding methods have been modified for use in areas having difficult grounding conditions. Satisfactory transmission line grounding in rocky areas is obtained economically where the improved methods are followed. Long rods are effective in reducing distribution neutral voltages to an acceptable sustained maximum of 15 volts, which introduces a negligible hazard.

Measurements taken on an air-switch installation showed the superiority, over that with rods alone of a grounding arrangement incorporating a mat or grid. On the basis of these tests, it is proposed to use such a mat to control the potentials possible between switch handle and ground. Personnel and equipment at generating stations under construction are protected from fault currents by connecting all equipment on the ungrounded distribution system to a common metallic circuit. Ground detectors are used if this arrangement is not practical. Completed stations are safely grounded both for power-frequency system faults and lightning surges. In most instance, separate grounding arrangements are necessary for each type of installation.

Jointing Aluminium Cable; P. A. Raine - Elec. Rev., Vol. 148, Mar. 16, 1951, pp. 529-31.

This article discusses the methods of wiping and soldering aluminium cables, sheath and stranded conductors (in 1951).

Design of Optimum Buried-Conductor RF Ground System; Frank R. Abbott - Proc. I.R.E. Vol. 40, No. 7, 1952, pp. 846-52.

From the design equations developed, a radial-conductor ground system may be constructed which will provide maximum power radiated per dollar of over-all cost. The fundamental equations are particularly applicable to any installation operating in the frequency range below 1,000 kc. A radial-conductor ground system based on the design parameters here presented will assure low-frequency antenna efficiencies of 50 percent or less usually encountered in similar antennas without such a ground system.

A technique for achieving optimum design of radial-conductor ground systems was developed. Curves were prepared which facilitate the determination of optimum spacing and length of the ground radials. A typical computation is included.

Mutual Impedance of Earth Return Circuits; L. J. Lacey - IEE Proc., Vol. 99, Pt. 4, pp. 156-167, 1952.

A highly mathematical, but rigorous, derivation of the mutual impedance between earth-return circuits, such as a 5 mile long power line and a nearby communication circuit.

Electrical Noise from Instrument Cables Subjected to Shock and Vibration; Thomas A. Perls - Journal of Appl. Phys., Vol. 23, 1952, pp. 674-680.

Existing information on the reduction of spurious signals from instrument cables is reviewed. A tentative theory is formulated to account for the known data. Subsequent experiments confirm this theory and allow the formulation of a detailed mechanism of noise generation in cables. The noise may be eliminated for practical purposes (reduced by a factor of 500 or more in some cases) by having continuous electrical conduction between both surfaces of the insulating dielectric and the adjacent conductors. A simple procedure is outlined to make short lengths of this cable for laboratory use, and an industrially applicable method is suggested. There appears to be no limit on how small the diameter of such cables could be made.

Neutral Grounding of Low-Voltage Systems; R. H. Kaufmann - Iron and Steel Engrg., Vol. 29, No. 2, Feb. 1952, pp. 96-103.

This article discusses the advantages, of neutral grounding in low-voltage systems. Also specific examples of a-c faults are presented and discussed.

Factors Affecting Generator Grounding: A. A. Johnson - Electric Light & Power, Mar. 1952, pp. 92-6.

General grounding to reduce fault currents must be a compromise to best suit conditions. However experience and judgment over the years have produced workable grounding methods that minimize fault damage.

Industrial Grounding: F. C. Soares - Electrical Construction and Maintenance, Vol. 51, No. 4, Apr. 1952, pp. 62-4.

This article tells how to ground industrial systems and equipment to assure: 1. Safety to life and property by reducing the damages that may be caused by a ground fault. 2. Reduction of power failures due to transient overvoltages. 3. Ease of locating ground faults. 4. Economy of operation, particularly at higher voltages.

Earth-leakage Protection in Parallel With a Solid Earth: N. Elliott - Proc. IEE, Vol. 99, June, 1952, pp. 250-4.

The trip coil of a voltage-operated earth-leakage circuit-breaker is likely in practice to be paralleled by a "solid" earth by reason of contact between the frame of the protected apparatus and fortuitously earthed metal. It is better to provide a parallel solid earth of known performance. In such a protective circuit the sensitivity of the voltage-operated trip of the circuit-breaker may be increased without fear of unwanted operation due to leakage from apparatus such as an electric cooker, adn there are advantages over the more usual method of connection without a solid earth in parallel.

Universal Skin Effect Chart for Conducting Materials: H. A. Wheeler - Electronics, Vol. 25, No. 11, Nov. 1952, p. 152.

Gives skin depth, napier depth and depth of penetration in various metals, solutions and ground at frequencies ranging from 1 hz to 1,000 GHz. One use is estimating transmission between underwater loop antennas, such as for sub-to-sub or sub-to-ship radio communication through salt water.

The Earthing of Telephone Systems with Particular Reference to South Africa: C. F. Boyce - South African Institute of Electrical Engrg., Vol. 43, Dec. 1952.

Provided the resistivity of the ground in the vicinity of a proposed earth electrode is known down to a depth of about 20 feet, the resistance of the earth connection may be calculated with a fair degree of accuracy.

A comparison of earth plates, grids, rods and horizontal wires reveals the superiority of the latter, particularly in the high-resistivity soils of South Africa.

The impulse characteristics of soil and various electrode systems are considered. It is concluded that the low-frequency resistance is an adequate criterion as far as telephone-system earths are concerned.

A brief survey is made of the ranges of resistivities likely to be encountered in soils and rocks in South Africa. Some practical suggestions are made for obtaining satisfactory earths, and a comparison of the costs of various earthing arrangements is given.

The more important overseas references are given together with several references pertaining to South Africa.

Determination of Resistance to Ground of Grounding Grids; A. J. Mc Crocklin, Jr., C. W. Wenlandt - AIEE Trans., Vol. 21, pp. 1062-4, Dec. 1952.

Measurements were made of resistance of grids immersed in a lake (= 420 micromhos per cm^3), and an expression (with curves of parameter values) in presented.

Grounding and Corrosion Protection on Underground Electric Power Cable Sheaths and Oil- or Gas-Filled Pipe Lines; Robert J. Kuhn - AIEE Trans., Vol. 71, Dec. 1952, pp. 990-993.

The general electrical-industry practice of "crossbanding" cable sheaths is reviewed. Corrosion problems created by protective grounding are cited, as are general remedies to prevent corrosion. The "paradox of grounding versus cathodic protection" is described, and specific solutions to the problem of obtaining satisfactory grounding and corrosion protection on underground electric cable sheaths and pipe lines are given. It is concluded that "For oil- or gas-filled pipe lines or for 3-conductor cables and even for single-conductor cables, especially when installed in individual ducts, practically complete corrosion protection is obtainable.

Grounding Shielded Cable; Michael Mangi, John M. Marenan, Morris Brenner - Electrical Manufacturer, Vol. 50, pp. 128-136, Dec., 1952.

Six methods of installing ground leads as shielded cables are described. A comparative evaluation is made as the basis for case and cost of assembly step.

Performance of Electrical Joints Utilizing New Silver Coating on Aluminum Conductors; T. J. Connor, W. R. Wilson - AIEE Trans. III, Vol. 74, 1953, pp. 702-712.

The subject of this paper is the preparation and evaluation of aluminum joints which will meet the high standards of performance now (1953) being maintained with electrical joints in switchgear. A new silver-plating process has been developed and is being used to replace the aluminum surface in the contact area with a silver surface, thereby eliminating in this region the much-discussed aluminum-oxide film. The silvering process is described and the result evaluated, with corrosion considerations being conspicuous and the effects minimized. Some rather extensive tables on joint treatments, resistance as a function of salt-spray duration, resistance versus humidity, and resistance versus heat are included.

The Shielding Factor of Underground-Cable Sheaths F. J. Jones - IEE Proc., Vol. 100, Pt. 4, pp. 34-38, 1953.

Two components of the shielding factor of sheathed, buried cable have been analyzed previously. The formulas for these two factors, sheath construction and the earth-return circuit, are quoted. A formula is derived for the third factor, the terminating impedance of sheath-to-ground.

Noise-Free Instrument Cable; Communications Engr., Mar. 1953, pp. 22, 37-40.

The article presents a new method of shielded cable fabrication developed at NBS which has very low internal noise under flexure.

Earthing of Low and Medium Voltage Distribution Systems in Regions of High Soil Resistivity; L. G. T. Roberts - Royal Engineers Journal, Vol. 67, Mar. 1953, pp. 16-35.

This report describes briefly four of the general methods of protective earthing in use today, viz.:

a. Direct earthing. b. Continuous earthwire (C.E.W.) c. Protective multiple earthing (P.M.E.) d. Earth-leakage circuit-breaker (E.L.C.B.)

The hazards of each method are tabulated from the incidence of faults, the statistics of which were extracted from Electrical Research Association reports available.

The methods of earthing are compared on the basis of efficiency of protection and comparison of each is made, based on costs.

Conclusions are drawn on the economics and degree of safety of the four methods of earthing described and from them it can be seen that the earth-leakage circuit-breaker appears to be the most economical method in most circumstances. In very few circumstances where the soil resistivity is high does either the continuous earthwire or the protective multiple earthing method become more economical than the earth-leakage circuit-breaker.

Appendix "A" gives warning on the use of certain ranges of megger for earth resistance measurement in regions of high soil resistivity.

Ships Electronics Interference Reduction Program Held Week of June 15, 1953, Washington, D.C.; International Electronics Engineering, Inc., Washington, D. C., June 15, 1953.

Technical papers --1. Some aspects of the shipboard radio interference reduction program of the ship and amphibious division. 2. Radar interference. 3. Methods of measuring transmitter harmonics in the presence of the fundamental frequency. 4. Interference reduction by design technique. 5. New developments in interference measuring equipment. 6. Limitations of DB meters in the measurement of transient interference. 7. Bonding, grounding and shielding considerations. 8. Communication transmitter interference. 9. Engineering report requirement. 10. Typical interference conditions in auxiliary class vessels. 11. Present status of the destroyer and submarine interference program. 12. Typical interference conditions aboard wooden hull vessels. 13. Interference ship alts. 14. Interference word in METU-5. 15. Interference training programs.

Analysis of the Delta Grounded Transformer; E. T. B. Gross, K. J. Rao - AIEE Trans., Vo.. 72, Aug. 1953, pp. 817-26.

It is considered good practice to operate power distribution and transmission systems grounded, by connecting one or more transformer neutrals to earth, either directly or through an impedance. It is sometimes desirable to ground both systems at the substation in which they are interconnected through transformers. If neutrals are provided on both sides of the transformer through appropriate connections of the high and low voltage windings, a tertiary transformer winding in delta connection becomes necessary; the addition of this normally idle winding leads to an increase in the size and cost of the transformer. Another solution is in wye-delta connection, and the installation of a separate grounding transformer on the delta-side; this solution has often been used, but it not only requires extra equipment, but also produces additional core losses, thereby leading to increased operating costs.

The delta-grounded transformer, first suggested by H. L. Hoeppner, is a satisfactory and economical solution to this problem. This paper is devoted to the analysis and discussion of the interesting circuit characteristics of this power transformer and grounding equipment

Grounding Grids for High-Voltage Stations; E. T. B. Gross, B. V. Chitnis, L. J. Stratton - AIEE Trans., Vol. 72, pp. 799-809, Aug. 1953.

An expression, and universal curves, or resistance of grounding grids is presented. Comparisons with experimental measurements shows agreement within about 10% for 1 to 9 meshes. In the method of subareas, capacitance is computed as a summation of subarea charge-to-voltage ratios. Since the voltage does not vary over the subareas, the method is based on approximating charge distributions over the grounding systems.

Design Charts for Determining Optimum Ground Rod Dimensions; J. Zaborszky and Joseph W. Rittenhouse - AIEE Trans., Vol. 72, pp. 810-817, Aug. 1953.

Charts and equations to aid in dimensioning a ground rod system. A 10 foot 3/4 inch vertically driven ground rod is used as reference, other systems are expressed as percentage ratios of the reference rod. Normalyzing parameters are resistance and weight, spacing and length, number and conductance, adn available area for the desired installation.

Earthing Practice; P. W. Cave - Electrical Review, Oct. 9, 1953, p. 793.

This article is essentially a summary of Mr. P. W. Cave's lecture. He discussed earthing under the three main headings of the earth electrode,

its connection to the earth terminal and bonding. Grounding by rods (vs. plates, strips, and pipes) is advocated, a representative range of soil resistivity is cited, and considerations of soil drying are mentioned. Possibly lethal soil "gradients" are noted (10 volts for cattle and 47 volts for man). Comments are included on earth electrode spacing and on bonding intervals and interface dimension.

Effect of Fault Resistance on Ground-Fault Current; Martin J. Lantz - AIEE Trans., Oct. 1953, pp. 1016-1019.

This article pertains virtually exclusively to the electrical power system engineer's concern with taking fault resistance (e.c., tower footing resistance related to line-to-tower arcing) into account in designing for power-line fault protection.

Grounding Electrode Characteristics from Model Tests; H. R. Armstrong - AIEE Trans., Vol. 72, Dec. 1953, pp. 1301-6.

Grounding electrode performance is of increasing importance as power system expansion results in greater ground fault currents. When many driven rods or pipes are connected together for an extended area such as a substation the characteristics are not readily predictable from published information. The fundamental theory of grounding electrodes has been well covered in the literature for small numbers of electrodes of simple shape. Data and charts are also available for determining the resistance of extended multiple-rod grounds. From basic considerations, it is possible to calculate the resistance and potential gradients for rods in multiple, but the influence of the buried connecting conductors is not readily evaluated. Moreover, it must be recognized that any calculation of grounding-electrode characteristics, except for ideal cases, is only a good approximation due to such factors as nonrigorous methods and the variability of soils. Consequently, a need is indicated for practical voltage-gradient and current-carrying data on multiple electrodes as they are commonly used by industry for equipment grounding.

This paper presents data obtained in the laboratory from tests on model electrodes in an electrolytic trough. Additionally, the specific heat and sparking potential of various soils was determined from tests on soil samples. These studies are discussed in six parts:

1. The model method. 2. Resistance and voltage gradients for multiple-rod electrodes. 3. Current distribution in an extended multiple-rod ground. 4. Current capacity of electrodes in various soils. 5. The sparking gradient of soils. 6. Field tests.

System Grounding in Industrial Plants; F. M. Dorey - Elec. Engrg., Vol. 72, No. 2, Dec. 1953, pp. 1098-1103.

Some of the reason why grounding is important are discussed together with various methods for satisfactory neutral grounding of 3-phase a-c systems in industrial plants.

Electrostatic Unbalance to Ground of Twin Conductor Lines; Eric T. B. Gross, W. J. Mc Nutt - AIEE Trans., Vol. 72, Dec. 1953, pp. 1288-96.

Inductive and capacitive unbalances are present in transmission lines which are not transposed. The modern trend has been to omit transpositions, and it is then desirable to compute the resultant unbalances. This paper deals with one phase of this problem as applied to twin conductor (bundle conductor) lines namely the electrostatic unbalance to ground which is a result of unequal capacitances between the three phases and ground. In a solidly grounded system, this unbalance manifests itself as a fundamental frequency, zero sequence current in the lead between the neutral and ground of the power transformer which is used for system grounding.

Compression Wye Splicing to Insulated Aluminum; Fred Heller - Trans. AIEE III, Vol. 73, 1954, pp. 1218-23.

The use of compression connectors for wye splicing of insulated aluminum conductors is described and tested.

Grounding of Subtransmission Systems; G. D. Breuer, I. B. Johnson, S. V. Lyon - AIEE Trans., Vol. 73, Pt. 3, 1954, pp. 1580-1585.

Subtransmission systems can be grounded through a solid connection, a resistance, a reactance, or a combination of resistance and reactance. In the selection of the method of grounding, several factors must be considered: 1. Relaying sensitivity; 2. magnitude of ground fault currents; 3. the degree of lightning and switching surge overvoltage protection obtained from the arrester rating applicable; 4. the severity and risk of switching transient overvoltages; and 5. relative cost.

High impedance grounding ($X/X > 3$ and $R/X > 1$ $X/X > 3$ and $R/X \leq 1$, or $X/X \leq 3$ and $R/X > 1$) has been recommended where it has offered economies in the current rations of grounding transformers and of neutral grounding devices. High impedance grounding, however, has involved problems of transient overvoltages. These overvoltages can be initiated

through restriking in the circuit breaker upon interruption of line-to-ground faults, or, as has been assumed in certain analyses, by faults in solid dielectrics. Restriking while interrupting ground-fault current should not occur in modern breakers. However, as systems will generally be equipped with old and new breakers, the possibility of restrikes occurring must be taken into account in studies of system grounding. Previous studies in establishing criteria for high impedance grounding have indicated that multiple restriking and consequent cumulative build-up in transient overvoltages can be eliminated provided the ratio X /X in the system does not exceed 10. Another suggested criterion to limit the severity of the transient voltages is that the ratio R /X of the ground path referred to the desired location on the system should be equal to or greater than 2 without regard to the ratio of X /X .

It is the purpose of this paper to evaluate the foregoing grounding criteria for high impedance grounding. This will be done by comparing previously used criteria with results of a study on systems in miniature on the transient network analyzer. Related questions of magnitude of fault current, relaying sensitivity, overvoltage protection, and lightning arrester rating, and relative costs will be evaluated.

<u>Analytical Expressions for the Resistance of Grounding Systems</u>; S. J. Schwarz - AIEE Trans., Vol. 73, pp. 1011-16, 1954.

A short, practical paper, which presents approximate expressions for resistances of grids, rodbeds, and combinations. Derivations are included, and agreement is shown with Dwight (AIEE Trans. Vol. 55, pp. 1319-28, Dec. 1936) and others.

<u>Equipment Grounding for Industrial Plants</u>; L. J. Carpenter - Electrical Engrg., Vol. 73, No. 3, Mar. 1954, pp. 256-260.

After pointing out what an important factor no grounding or inadequate grounding has been in electrical work injuries, the components of an equipment grounding system are discussed. Then the grounding of power station and distribution equipment stationary utilization equipment, and portable equipment are considered.

<u>Cathodic Protection for Steel Mill Grounding Systems</u>; J. F. Headlee - Iron and Steel Engineer, Vol. 31 (3), Mar. 1954, pp. 113-115.

This article gives a "quickie" review of the fundamentals of corrosion versus udnerground metallic structures and describes a method of cathodic protection against galvanic corrosion, as designed and

installed at the Fairless Works of U.S. Steel, integrally with the electrical grounding system there.

<u>Application Guide on Methods of Substation Grounding</u>; AIEE Commitee Report - AIEE Trans., Vol. 73, Apr. 1954, pp. 271-7.

The purpose of this guide is to summarize the present-day practices in substation grounding and, where possible, to make recommendations. This guide is based upon 61 answers received from a questionnaire on substation grounding practices. Answers were received from all types of electric utilities, large and small, metropolitan and rural, in all parts of the nation.

<u>Grounded Versus Ungrounded Low-Voltage A-C Systems</u>; H. B. Thacker - Iron & Steel Engrg., Vol. 31, No. 4, Apr. 1954, pp. 65-72.

This article presents the advantages and disadvantages of both grounded and ungrounded low-voltage a-c systems.

<u>Shielding Nomograph</u>; J. F. Sodaro - Electronics, Vol. 27, No. 5, p. 190, May 1954.

Attenuation chart simplifies design calculations for shielded rooms, filter enclosures, coaxial cables and chassis construction materials. Effectiveness of shielding can be determined for both magnetic and nonmagnetic materials.

<u>Electric Shock, Its Causes and Its Prevention</u>; R. L. Kline, Dr. J. B. Friauf - BuShips Journal, July 1954, pp. 4-14.

This article, written in a popularized vein, gives statistics and some particulars on electri-shock fatalities in the U.S. Navy, both on shipboard and ashore, for 1946-1952 inclusive. It then goes into some detail about human and nonhuman failures involved and about the types of circuits a man can become a part of in a shock incident. Various generalized cautions are included. The remainder of the article is devoted to "do's" and "don'ts" with emphasis on their applications to Navy personnel and to typical Navy circuitry (e.g., ungrounded systems).

Hazards in Industrial Electric Systems; R. H. Kaufman - Safety Maintenance & Production, Aug. 1054, p. 26.

This technical news item quotes G.E.'s R. H. Kaufman on two primary and two or three secondary criteria he observed as necessary in protective grounding systems to insure freedom from hazard to life and property.

An Effective Ground Conductivity Map for Continental United States; Harry Fine - Proc. IRE, Vol. 42, No. 9, Sept. 1954, p. 1405.

The Federal Communications Commission has recently adopted a new effective ground conductivity map. The derivation of this map and its estimated accuracy are discussed in this paper.

Shielding and Potting S. J. Burruano, E. F. Bailey, S. Cramer - Electronics, Vol. 27, No. 10, p. M-23, Oct. 1954.

Fabrication of electrostatic and electromagnetic shielding for optimum electrical performance and potting, embedding and encapsulating techniques required to guard against moisture, fungus or accidental short circuits are discussed.

Some Fundamentals of Equipment-Grounding Circuit Design; R. H. Kaufmann - AIEE Trans., Vol. 73, Nov. 1954, pp. 227-232.

An effective equipment-grounding system should, under conditions of maximum ground-fault current flow, accomplish the following objectives: 1. maintain a low potential difference, perhaps 50 volts maximum, between machine frames, equipment enclosures, conductor enclosures, building metallic structure, and metallic components contained therein to avoid electric shock hazard and unwanted circulating current, and 2. incorporate adequate conductance to carry this maximum ground short-circuit current without thermal distress and the attendant fire hazard. There is good reason to believe that current flow in the equipment-grounding system in a-c power systems will not stray far from the power cable over which the outgoing current flows. It follows that the installation of conductive material in an equipment ground system unless properly located can be ineffective and wasteful, and can create a false sense of security. This paper presents the results of a special series of full-scale tests dealing with this specific problem and a general analysis of the circuit behavior.

Electrical Interference in Instrumentation - Its Causes and Remedies: James C. Coe - ISA Journal, Nov. 1954, pp. 49-50.

The paper is presented for those interested in sizable instrumentation installations, and especially where a large number of control and power circuits are required near instrumentation circuits or equipment. There the likelihood of interaction with resulting errors of malfunctioning of instrumentation equipment presents a serious problem. The causes are covered along with general rules for reducing the interaction. Interference may be reduced at the source, the means by which it is transferred to the instrumentation may be reduced, or corrective action may be taken after it is transferred, or any combination of the three.

Earthing Electrical Installations: A. G. Thomson - The Chemical Age, Dec. 4, 1954, pp. 1198-1200.

This article is concerned only with the precautions necessary to ensure safety in plants (primarily chemical). The approach is taken that "it is usually impossible to dissociate safety to operatives from what may be essentially protection of plant." The installation of main system "earths" is outside the scope of this article.

Radio Interference Control in Aircraft: A. L. Albin, J. E. Mc Manus - IRE Aero, Electronics Digest, 1955, pp. 268-271.

The article is a summary of radio-interference in aircraft. It defines those radio-interference parameters and design techniques, commonly described as "good engineering practice", yet frequently overlooked in the planning stage.

Electrical Grounding Systems and Corrosion: L. P. Shaeffer, F. F. Kulman, S. S. Watkins - Trans. of AIEE, Vol. 74, 1955, pp. 75-83.

The object of this paper is to consider the proper conduction of electric currents to the earth resulting in adequate grounding, and also conduction of currents through the earth resulting in corrosion or the prevention of corrosion. Mr. Schaefer's comprehensive paper discusses and clarifies the conflicting requirements of grounding and corrosion protection of underground structures.

Cathodic Protection Circuits: E. W. Schwarz, R. M. Wainwright - AIEE Trans., Vol. 74, 1955, pp. 311-315.

This paper, primarily on corrosion of metallic surface in soils and solutions, begins with a statement of the problem and its electrochemical nature and progresses through arguments for theoretical versus empirical attacks. Then, with the aid of equivalent circuits, it goes through mode and mesh equations explaining the corroding cell as an electrical, logical phenomenon.

<u>The Right Way to Ground Generator Neutrals</u>; Ben H. Smith - Power, Vol. 99, 1955, pp. 124-5.

The real reasons for grounding generator neutrals, in both industrial and municipal units, are presented. Also the how-to side of the picture is discussed.

<u>Electrical Grounding and Cathodic Protection at the Fairless Works</u>; W. E. Coleman, H. G. Frostick - AIEE Trans., Mar. 1955, pp. 19-24.

This article describes U.S. Steel's Fairless Works' combination electrical grounding system and cathodic protection system in considerable detail. It includes such things as earthing-system layouts, installation details, hardware details, and soil resistance resistivity data for that installation.

<u>The Search for Better Frame-Grounding Methods</u>; L. H. Harrison - Coal Age, Feb. 1955, pp. 84-7.

Here is a down-to-earth review of 1. the problems of frame-grounding underground units powered through trailing cables, 2. some possible solutions as embodied in systems now undergoing tests and 3. the challenge to coal's electrical fraternity to devise still better systems.

<u>Equipment Grounding: Is it Really Protecting Your Plant?</u>; R. H. Kaufmann - Power, Feb. 1955, pp. 77-80.

A heavy bonding system to structural steel and water pipes may be giving you a false sense of security. Tests prove major chunk of ground-fault currents tend to return on the power conduit or on grounding cable within such conduits.

Bolted Connections in Aluminium Busbars ; J. C. Bailey - The Engineer, Vol. 199, Apr. 22, 1955, pp. 551-4.

The performance of bolted connections in busbars has frequently been criticised because of the tendency observed in some instances for high resistance to develop with the passage of time. This review of the data available indicates the essential factors in good jointing technique: and covers both laboratory studies and practical experience over thirty years. The first section summarizes laboratory experiemnts, the second discusses observations and experience with actual busbar installations; and the final section gives recommendations regarding the essential requriements to be met for achieving bolted busbar joints of satisfactory low resistance and good stability.

The Shielding of Radio Waves by Conductive Coatings; E. L. Hill - IRE Trans. on Antennas and Propagation, Vol. 3, No. 2, Apr. 1955, pp. 72-6.

A theory is given of the shielding of radio waves by the conducting coatings which are placed over the cockpit dome and windows of an airplane. At low and medium frequencies the shielding arises primarily from the quasi-electrostatic charges which are induced on the surface, the effects of which increase strongly with decreasing frequency. At higher frequencies the shielding from this source diminishes in importance while that from the induced eddy currents increases in effectiveness.

Grounding Shield Braid in Guided Missiles; John Markus - Electronics, Vol. 26, No. 4, p. 240, Apr. 1955.

Several methods to ground shield braid pigtails, when most or all wires to a terminal strip are shielded, are discussed.

Interference Suppression; R. Davidson - Wireless World, April, 1955.

This article is a "discussion-type" review of interference suppression techniques for dealing with small commutator motors in the mid 50's. It reviews the general principles of suppression and describes the latest interference suppression methods for small electric motors used in domestic and industrial apparatus in Great Britain.

All Steel Network Grounds Substation; Glen Appleman, S. J. Litrides - Electrical World, Vol. 143, pp. 59-61, May 2, 1955.

The Pennsylvania Power and Light Co. had abandoned driven steel ground rods and pipes (except for small grounding networks). Galvanic action between the steel rods and copper conductors had corroded the zinc from the rods, had then corroded the steel rods, and had even damaged conduits, footings, cable sheathing, pipes, etc. Steel towers grounded by copper were likewise damaged. Obvious solution to galvanic action in the electrolytic earth environment is to use one metal only, i.e. steel. All underground conduity, pipes, conductors, structures, etc. should be steel.

<u>Let's Look to Station Grounding</u>; Stephen J. Schwarz - Electrical World, Vol. 143, May, 1955, pp. 55-8.

Considerable confusion prevails in the present-day (1955) design of grounding systems for power plants and substations due to a lack of simple mathematical analysis. This article discusses a new concept for computing ground resistances of grid and rod arrangements which shows that many generally accepted practices today (1955) can be simplified resulting in greatly reduced costs.

<u>Earth Leakage Protection</u>; T. C. Gilbert - Electrical Rev., June 1955, pp. 985-7.

A discussion-type article of voltage operated trips in domestic installations of the 50's. The author concludes that local application of voltage operated trips is the logical answer to problems of effective leakage protection.

<u>Coming: More Grounded Systems</u>; H. B. Thacker - Factory Management and Maintenance Vol. 113, No. 10, Oct. 1955, pp. 132-5.

What's behind the trend? Here's expert advice to help you decide between a grounded electrical distribution system and the old standby, and ungrounded one. This advice is for every plant operating man, and must reading for anyone planning a new plant.

<u>Wiring Design to Avoid Pickup</u>; Gerald Weiss - Product Engineering, Product Design Handbook Issue, Mid-Oct. 1955, pp. 6-9.

Inattention to wiring design is a common source of troubles that often spoil the performance of expertly conceived control systems in the low frequency band between 60 and 1,000 cycles per second.

A wire is a piece of equipment with mechanical and electrical properties. It has resistance, capacitance, and self-inductance. Similarly, a group of wires exhibits mutual capacitance and mutual inductance. With proper design based on elementary electric circuit theory, most system difficulties can be anticipated and prevented before an application malfunction occurs.

The techniques discussed here pertain specifically to a-c servos, computers, and similar electromechanical equipment. They also apply, however, to a wide variety of other measurement and control systems operating off low frequency alternating current supplies.

A computer may be carefully designed, built according to specifications, and then found to be operating improperly. The static error of the servos is excessive, gain is low, and undesirable oscillations are observed. Measurements may show large quadrature and harmonic voltages, excessive power supply ripple, and zero offsets in resolvers, synchros, or potentiometers. When a recheck of the design shows no apparent errors, the trouble can usually be traced to pickup in the circuit wiring.

<u>Grounding Grids for High-Voltage Stations - Resistance of Large Rectangular Plates</u>; Eric T. B. Gross, Richard B. Wise - AIEE Trans., Vol. 74, pp. 801-809, Oct., 1955.

The Maxwell method of subareas is extended to plates (see paper by E.T.B. Gross, et al, on Grounding Grids, AIEE Trans., pp. 799-809, Aug. 1953).

<u>Efficiency of Grounding Grids With Nonuniform Soil</u>; J. Zaborszky - AIEE Trans., Vol. 74, pp. 1230-1233, Dec. 1955.

Assumptions for mathematical model were concentric rings (round, thin conductors) buried in uniform soil over uniform, high resistivity rods, with radii of rings such that uniform conductor density results. It is shown that increasing grid ring radius lowers the ground resistance; conductor radius has little effect on ground resistance; on a basis of a given conductor length, a single ring is more efficient than a grid.

<u>Direct Currents and Corrosion as Related to AC Electric System Grounding</u>; Orville W. Zastrow - Direct Current, Vol. 2, No. 7, Dec. 1955, pp. 183-6.

Direct currents and voltages in neutral conductors of electric distribution lines provide valuable information about underground corrosion associated with the electrical grounding. This relationship of direct currents to corrosion phenomena is well known to corrosion investigators but apparently it is overlooked by many electric utility engineers. However, experience indicates that direct currents will flow in grounding networks (even if they were designed with only alternating currents in mind) and that relatively small direct currents may be important from the standpoint of underground corrosion.

The measurement of direct currents in grounding networks requires different measuring techniques than measurements performed, for example, on an underground pipeline. Interpretation of the measurements in terms of corrosion damage raises additional questions, since the significance of the measured current or voltage in a particular case depends on local conditions. This article describes some experiences in the use and interpretation of direct current measurements in corrosion studies.

The Reduction of Radio Interference in Aeronautical Communications Systems; Arnold L. Albin, Herbert M. Sachs - IRE Trans. on Comm. Systems, Vol. 4, 1956, pp. 107-113.

Radio interference suppression must be considered in early design stages for maximum effectiveness. The chief sources of interference to communication systems are spurious ans harmonic radiations, corona and precipitation static, and co-channel and adjacent-channel interference. Other interference source such as ignition systems, rotating machinery and contacting devices are not included in the scope of this paper. Interference may render some equipments inoperative or produce distortion in others. Most types of interference can be successfully eliminated by the reduction of transmitter spurious radiation, reduction of receiver susceptibility, antenna design to reduce mutual coupling, and judicious frequency assignments.

Crosstalk on Open-Wire Lines; W. C. Babcock, Esther Rentrop, C. S. Thaeler - Bell System Technical Journal, Mar. 1956, pp. 515-518.

This article appears to abstract a Bell monograph which in turn supplements a paper titled "Open-Wire Crosstalk". It briefly discusses types of crosstalk coupling and companion affects and tells what the monograph includes in its (presumably) more comprehensive and more quantitative presentation.

High Frequency Shields; Raymond E. Lafferty - IRE National Conv. Rec., pp. 151-158, 1956.

Calculations and measurements of Q of cylindrical shield cans are presented, for the cases of (1) skin depth greater than and (2) less than wall thickness.

The Purpose and Design of a Substation Ground Network; J. G. Wynne - Pulp and Paper Magazine of Canada, Convention Issue, 1956.

The Anglo-Canadian Pulp and Paper Mills, Limited at Quebec are building a new outdoor substation. At the time of writing, this substation is in the early stages of construction. The power will be received at 230 kv. and stepped down to 6.9 kv. and 13.8 kv. When completed, it will consist of three banks of transformers, each rated 25/33/40 MVA, with space and switching available for installation of a fourth transformer should it be needed in the future. The general substation layout is shown in Fig. 1. This paper deals with the ground network for this substation.

Cross Pulse Pickup in Twisted-Pair Cables; J. G. Stephenson - Electronics, Vol. 29, No. 2, p. 170, Feb. 1956.

To reduce bulk and expense in station layouts, engineers are often tempted to use twisted-pair cable instead of coaxial cable. Chart showing pickup in various kinds of cable indicates when this practice is acceptable.

Interference Suppression for Air Force Ground Electronic-Communications Equipment; J. Berliner, R. Powers - Proc. 2nd ARF Conf. pp. 6-11, Mar. 1956.

With the advent of higher power ground electronic-communications equipment, more highly sensitive receivers, and a greater number of these equipments operating in close proximity, the problem of interference has increased by a very large factor. The need, therefore, has arisen for interference specifications which should include practical interference levels and improved interference measuring equipment and techniques over a wider practical frequency range. An attempt has been made in this paper to point out the interference specification requirements peculiar to Air Force ground electronic-communications equipment. For the benefit of those present who are not familiar with Rome Air Development Center reponsibility in the field of interference suppression, a description of this function has also been

included. Interference R&D activities at RADC are also briefly described.

Crosstalk Between Coaxial Conductors in Cable; R. P. Booth, T. M. Odarenko - B.S.T.T. pp. 358-384, Mar., 1956.

Tertiary coupling of sheath and quads (additional metal which is near to but insulated from coaxial conductors in a telephone cable) increases attenuation between coax lines. The study delineates how terminating the tertiary circuit, and transposing coaxial line sections decrease crosstalk. Parameters for the study were line length (73 feet to 5 miles) frequency (40KHz to 800KHz) for lines up to about 700 feet for end crosstalk increases at about 6 dB per octave, then is constant to about 10,000 feet. From 10,000 to 30,000 feet, it again increases at about 5 db/octave. Values for 700 feet, at 50, 100, and 200 MHz, were measured at 106 dB, 112 dB, 118 dB.

Radio Interference Problems on the B-57; V. C. Plantz , L. C. Simms - Proc. 2nd ARF Conf. pp. 183-188, Mar. 1956.

Numerous interference problems were encountered during the test programs conducted on the B-57 aircraft. Martin engineers found interphone system hum and noise, pulse-equipment interference in the ADF and in the UHF communications equipment, UHF transmitter interference in navigation equipment, and interference in the ADF from a camera control system.

To shorten the time taken in testing aircraft, a comprehensive bench test interference program was undertaken on nearly all items of electrical and electronic equipment to be installed.

Reduction of interference in the interphone system involved rerouting of cable runs and careful attention to shielding and grounding details of the installation. In the ADF equipment some success was had with coaxial cable traps and special filters. No significant improvement was obtained in the pulse-equipment interference in the UHF because of shared-band operation of the two sets. The camera control system problem was solved by extensive use of L-C and R-C filters of special design.

Research Investigations of the Radio Frequency Shielding Effectiveness of Screening Materials; E. R. Radford - Proc. 2nd ARF Conf., pp. 297-307, Mar., 1956.

The purpose of this report is to describe the work accomplished on the development of a screening material with high radio noise attenuation offering small resistance to air flow. Previous studies of screen materials revealed the top practical limit of attenuation for a single layer is about 60 db.

RF Tightness Using Resilient Metallic Gaskets; O. P. Schreiber - Proc. 2nd ARF Conf., pp. 343-359, Mar., 1956.

It is well known that radio interference can be contained within electronic equipment by thorough filtering and shielding. The filtering contains the conducted interference and the shielding the radiated interference. In this paper only the shielding phase will be considered. Ideally, the shield should be a continuous piece of highly conducting material completely surrounding the equipment. This is never a practical solution since openings through the shielding are needed for accessibility, ventilation, controls, meters, etc. Therefore, the problem of making a shield RF tight resolves itself basically to making these necessary openings RF tight. Long narrow cracks, such as occur in the joints between sections of a shield which are necessary for good accessibility, are particularly troublesome. A simple solution to this problem is the use of a material which is both resilient and conductive; in other words, a resilient metallic gasket. Various forms of such gaskets will be discussed; in particular, knitted wire mesh gaskets.

Why Ground; O. K. Coleman - Elec. Engrg., Vol. 75, No. 5, May 1956, pp. 418-24.

This brief summary of the sometimes misunderstood subject of grounding is from notes the author has used, and continually revised, for several years in discussion at inspector and contractor meetings in connection with National Electrical Code work. Although many safety problems are solved by grounding, it is pointed out that isolation or insulation, where it can be accomplished, may better serve the purpose.

'Grounding' - Center of Confusion; Tom Hughes - Electrical West, Vol. 115, No. 5, Nov. 1955 and No. 6, Dec. 1955; Vol. 116, No. 1, Jan. 1956; No. 3, Mar. 1956; No. 4, Apr. 1956; and No. 5, May 1956.

This series of six short articles is written around the theme that different people mean different things by the term "grounding." A number of different concepts are presented, and a case is made (from the author's viewpoint) that a fault current return is the main concern. A number of potential "ground" related hazards, with both fixed and

portable equipment, are presented, along with proposed or implied solutions or improvements.

Corrosion Can Conquer Your Grounding System; L. P. Schaefer - Industry & Power, Vol. 71, June 1956.

This article treats earthing system electrical requirements relative to applications and how to achieve these requirements and sustain them against corrosion tendencies. The article is slanted toward building/plant grounding.

Radio Interference Suppression; Depts. of the Army and Air Force, TM 11-483 to 31-3-9; Oct. 1956.

This manual contains information on radio interference suppression as it applies to the communication officer, operator and maintenance technician. The causes of natural, man-made, and mutual interference and the proper techniques that may be taken to eliminate these from communication equipment are also described.

How Good Are Your System Grounds?; Power, Plant Operating and Maintenance Section, Oct. 1956, pp. 120-121, 190.

This aritcle takes the approach that "the ground connections on an industrial plant's electrical system usually don't get much attention until there is trouble." Specific troubles are cited, as are clues to trouble and its avoidance and a description of the ball-of-potential measurement method.

Connector Performance by Types; O. A. Boyer, E. Korges - AIEE Trans. III, Vol. 75, Oct. 1956, pp. 907-13.

This paper presents the results of a continuing test investigating the problem of connectors for joining conductors under nontension conditions.

Grounding Grids for High-Voltage Stations III - Resistance of Rectangular Grids; Eric T. B. Gross, Robert S. Hollitch - AIEE Trans., Vol 75, pp. 926-935, Oct. 1956.

This paper extends the technique of Maxwell's subareas to rectangular grids. Paper No. I in the series considered only square grids. It is shown that (1) the use of greater than 16 meshes is not practical, (2) as the length-to-width ratio is increased (by increasing the number of meshes) the incremental decrease in resistance becomes negligible, and (3) for d/w ratio > 4000, the decrease in resistance of a single mesh rectangular (4x=1.5) grid decreases only very slowly. (4) The resistance at d/w = 4000 is only about 7% less than at the surface.

Some Problems of Aluminium Connexion; C. T. Marx - The issue in November 1956, of a new British Standard 2791:1956, covering aluminium conductors in insulated cables, is further evidence of the trend observed in the electrical industry in recent years to make more extensive use of aluminium as a conductor material. In this article methods and problems of connecting aluminium are discussed and attention is drawn to difference in practice between copper and aluminium connexion.

Practical Handbook for Location and Prevention of RI From Overhead Power Lines; J. C. Senn, D. B. Wright - U.S. Civil Engrg. Research and Evaluation Lab, PB 131017, OTS, U.S. D.O.C., Nov. 1956.

This report achieves a brief, concise presentation of the EMI problems associated with power distribution systems and provides a ready reference for some of the more common control methods and procedures.

Fundamentals of Jointing Processes for Aluminium; J. C. Bailey, P. Gregory - Symposium on Aluminum & its Alloys in E.E., 1957, pp. 39-56.

This paper briefly surveys those jointing processes that are generally applied to aluminium in fields other than electrical engineering, with the object of exploring their application to the jointing of electrical conductors. This unorthodox approach to jointing problems is deliberate and, in the opinion of the authors, is fully justified at the present stage; it reveals that aluminium can be jointed as readily as copper, and in some instances more readily. No difficulty is experienced in soldering aluminium cable sheaths.

Attention is drawn to the advantages of fushion welding, resistance welding, and pressure welding, which yield permanent low resistance joints, and to brazing which is equally suitable. It is also suggested that crimped joints involving deformation of the conductor are particularly appropriate to aluminium, whilst methods familiar to copper

such as bolting, clamping and soldering can be successfully applied with appropriate modifications.

<u>Earth Fault Protection</u>; S. J. Emerson - Electrical Journal, Jan. 1957, pp. 183-184.

The article is a summary of a lecture given by Mr. Emerson entitled "Protective Multiple Earthing and Earthed Concentric Systems." It deals entirely with protective multiple earthing (PME) and PME's comparison to direct earthing. It is concluded that PME is favored in Germany and Australia. Also it has been seen that experience and fairly satisfactory results are being obtained as a result of experiments being carried out in this country. The author feels, however, that it would be a grave error to pursue the widespread use of PME until much more experience is gained.

<u>An Analysis of the Radio-Interference Characteristics of Bundled Conductors</u>; G. E. Adams - AIEE Trans., Vol. 75, Feb. 1957, pp. 1569-1584.

Extra high-voltage transmission systems of 330 kv and 400 kv have been in successful operation for some time. Experiences gained from operation of these lines have indicated that bundle conductors will be used on lines of 400 kv and over to maintain tolerable radio interference levels without having to use excessively large single conductors. In addition, the performance of bundle conductors with regard to radio interference and transmission capability on lines of 350 kv and under should at least be considered while planning a transmission system. Thus, considerable interest can be expected in the radio-interference performance of bundled conductors.

<u>RF-Interference-Free Design Techniques in Radar Systems</u>; E. R. Radford - Proc. 3rd ARF Conference, pp. 35-46, Feb. 1957.

Important factors that must be considered in effectively eliminating spurious RF radiation, the difficulties encountered, and effective methods of alleviating these difficulties, are discussed. The judicious application and orientation of components with contemporary design techniques have made vast strides into the art of RF interference suppression.

Theoretical Formulas for Calculating the Shielding Effectiveness of Perfor. Sheets and Wire Mesh Screens; J. P. Quine - Proc. 3rd ARF Conference, pp. 315-329, Feb. 1957.

This paper discusses the attentuation characteristics of perforated conducting sheets and single layer wire mesh screens. Formulas are derived for calculating the high and low impedance attenuations obtained when such materials are employed to cover an aperture in an equipment cabinet. It is shown that, for any particular screening material, the attenuation obtained is proportional to the first power of the aperture linear dimensions, and that, for any particular aperture being covered, the attenuation is inversely proportional to the cube of the perforation center to center dimension (spacing).

The cubic relation stated above applies only in the case of perforations in infinitely thin sheets. For finite sheet thicknesses, each perforation can be treated as a cutoff waveguide. The increase in attenuation with thickness can be calculated from a knowledge of the attenuation rate of the appropriate waveguide mode.

The Measurement of Earth-loop Resistance; G. F. Tagg - Proc. IEE, Vol. 104, Feb., 1957, pp. 215-28.

Regulation No. 507 in The Institution's Regulations for the Electrical Equipment of Buildings calls for a measurement of the earth-loop impedance and gives a method by which this can be done. Several instruments have been devised and are available to carry out this test, but all draw their testing current from the mains and are thus liable to serious errors. Records taken with a recording voltmeter show that in most cases there is already a voltage drop in the neutral conductor which is varying continuously and rapidly. It is shown both theoretically and by practical tests that instruments of this character can have errors under these conditions amounting to 100% or more. Any instrument intended to carry out these tests must be such that it will give the correct value despite the presence of the continuously varying voltage drop in the neutral. An instrument is described which draws its testing current from its own hand-driven generator and is free from these erros. The Regulation also calls for a measurement of impedance, but it is suggested that in most cases the difference between impedance and resistance of an earth loop is so small that an instrument measuring resistance will be sufficient.

The Control of Interference Through Basic Design; L. W. Thomas - Proc. 3rd ARF Conference pp. 356-360, Feb. 1957.

This paper deals, not with the suppression of radio interference, but with the control of it in the basic design of equipments. Both electronic and electromechanical devices are considered and design practices pointed out for each case.

A New Technique for Evaluating RF Leakage and Susceptibility of Electronic Equipment; C. S. Vasaka - Proc. 3rd ARF Conference, pp. 47, Feb. 1957.

This paper discusses the problems involved in radio interference leakage and describes the development of a new technique for evaluating the susceptibility of electronic equipment used in aircraft. Two basic problems exist in the radio interference evaluation of electronic equipment. One deals with the evaluation and control requirements of the RF leakage emanating from the equipment. The other involves the evaluation and control requirements of the susceptibility of the same equipment to extraneous signals. The new test method was developed on the basis of actual test results and was made as practical and simple as possible. Essentially the method consists of close proximity probing of the equipment under test with intense fields. A small 3 inch, 1 turn, electrostatically shielded loop is used, fed by a 50-ohm cable, and powered by a standard 50-ohm signal generator. During measurements records are made of the open circuit voltage output of the signal generator.

Data is submitted for the allowable susceptibility limits and control requirements that the best designed electronic equipments can meet at present. Data is also submitted on the relative magnitude and effect of excessive transmitter leakages to indicate the incompatibility with present day susceptibility requirements. A detailed description is given of the new test method in a form suitable for use in Specification testing from 0.15 to 1000Mc.

Quicker and Simpler Means for Interference Detection and Suppression; P. B. Wilson, Jr. - Proc. 3rd ARF Conference, pp. 72-77, Feb. 1957.

The rapidly expanding field of interference detection and suppression requires the use of quicker techniques and simpler instrumentation. By the use of broadband-conducted measuring techniques, it is possible to provide instrumentation which may be used by less skilled personnel to do trouble-shooting, monitor quality control and provide an inexpensive means for checking all production rather than sampling. This method also provides a means for detection of malfunctioning of electrical and electronic equipment; the detection of the presence of interference on power lines and is an aid in the design of less expensive test equipment

As these techniques are not widely known, it has been found that operators have to be trained to recognize and interpret results. A discussion of how personnel should be trained, to recognize what certain results mean, is covered by actual examples of uses of these techniques over a period of three years and by demonstrating the use of simpler instrumentation.

Let's Look at Electrical Grounds; W. H. Stewart - Pipe Line Industry, Vol. 6, No. 3, Mar. 1957, pp. 37-8.

Problems of grounding electrical equipment requires careful study. Here is a practical approach that makes use of grounds that are "ready-made."

Electronics Interference Reduction Aboard Naval Vessels; ~~E.~~ H. Davis - Proc. 3rd ARF Conference, pp. 375-390, Feb. 1957.

This paper discusses the policies concerning the scope of the Navy Interference Reduction Program, and describes in some detail, the part played by the Naval Shipyards in their endeavor to achieve the degree of interference reduction necessary to provide satisfactory military electronics operations. It discusses the causes and effects of electronics interference found aboard Naval Vessels. It describes the interference reduction procedures, methods and techniques used by the Long Beach Naval Shipyard in locating, identifying, isolating and correcting shipboard interference deficiencies. It contains a description of the conduct of an actual electronics interference survey on a Navy ship at sea, lists the electronic equipment used, and shows the close coordination and cooperation required of all participating personnel. The paper also touches upon the personal hardships endured by interference reduction engineers in working out during the continued rigorous trips at sea.

Radio Interference Definitions & Measurements; Study of Electronic Interference Vulnerability, Project Monmouth III (u); J. C. Try - RCA, Defense Electronics Products Department, Camden, New Jersey, 2nd Quarter Progress Report, Mar. 1 - June 1, 1957, Contract DA-36-039-SC-73119.

During this report period a literature survey was conducted in order to formalize, compile and define the effects of radio interference in communications equipments. The results of this survey entitled "Radio Interference Definitions and Measurements" appear in Appendix A of this report. Included in Appendix B is a list of characteristic spurious responses and emissions for some existing military and commercial

communications equipment. These data were compiled by RCA Eng. Standards Department from past measurements made on these equipments.

Recommended Grounding Practices for Single-Polarity D-C Structures; AIEE Committee Report - AIEE Trans., Vol. 76, Oct. 1957, pp. 784-90.

Recommendations for grounding metal structures surrounding single-polarity d-c circuits are different from those for surrounding ungrounded d-c or a-c systems. For more than 50 years, it has been common practice to insulate the surrounding structures of d-c apparatus (300 volts and over) where one polarity is grounded and switching is done only on the opposite polarity. When the electric system is ungrounded, 2-pole circuit breakers are used and the surrounding structures are grounded as explained in AIEE Report No. 953. Case histories show that danger to personnel results from high currents rather than high voltage. Applications in the mining, heavy industrial (steel mill for example), railway, and electrochemical fields are separately discussed and recommendations drawn for the maximum safety to personnel and equipment.

Earth-Electrode Systems for Large Electric Stations ; J. D. Humphries - Proc. Instn. Electrical Engrs., Vol. 104, pt. A, Oct. 1957, pp. 383-92, 392-99.

Interconnected systems have increased considerably in recent years, and the large possible earth-fault currents resulting require further thought being given to earth system design, especially in areas of high soil resistivity. The paper discusses the special practical problems of the design, construction and testing of earth electrode systems for stations with possible earth-fault currents in excess of 3kA. The basic components are reviewed, and principles of design are suggested for power station and large substation earthing installations. Several examples are considered in detail and brief notes are given of a number of large earth electrodes is discussed, and new techniques of resistance measurement which have been specially developed for use with large installations are described.

The Effective Electrical Constants of Soil at Low Frequencies; J. R. Wait - IRE Proc., Oct. 1957, pp. 1411-12.

This is a brief article (1 page) in the Correspondence Section of Proc. of IRE.

The author states that the purpose of this note is to present a simple phenomenological theory for the measured behavior of alternating current conduction in soils and rocks and low radio frequencies.

Aluminium Busbars ; Mechanical and Electrical Difficulties Overcome; H. B. Grainger, R. J. Watkins - Engineering, Vol. 184, Dec. 13, 1957, pp. 744-48.

Economic conditions have led electrical engineers to restrict their use of copper as far as possible for busbars, aluminium has the double attraction of cheapness and lightness. However, the mechanical strength of pure aluminium, and the difficulties involved in making low resistance pressure joints have retarded its adoption. This article describes the development of an alloy with a mechanical strength approximating that of copper, while yet retaining an acceptable conductivity, and also the development of a jointing compound which can be used by semiskilled operators to give stable low resistance joints.

Now It's Equipment Grounding; R. H. Kaufman - Factory Management & Maintenance, Vol. 115, No. 12, Dec. 1957, pp. 150-153.

It will guard your workers against shock, protect your plant against fire. That's why its worth doing right. Here's the how-to, from an expert who knows.

Reducing Electrical Interference; Edward S. Ida - Control Engineering, Vol. 9, 1959, pp. 107-111.

After discussing several types of interference that can and do degrade process instrument performance, the author shows how to get cleaner control signals by proper use of shielding, by avoiding ground loops, and by balancing of transmission lines.

Earthing of Low- and Medium-Voltage Distribution Systems and Equipment; F. Mather - Proc. IEE, Vol. 105, 1958, pp. 97-111.

The paper states briefly the reasons for earthing low- and medium-voltage distribution systems and equipment. Reference is made to various methods of earthing and to the main difficulties encountered in putting them into practice, particularly in rural areas.

The main objects are to describe the development of the system known as protective multiple earthing, to show the advantages of this system and to explain the reasons for its adoption on a wide scale in the rural zones served by the North Western Electricity Board.

The experience of the Board with the p.m.e. system from 1949 onwards is described.

A Compendium of Grounding Techniques for Personnel and Equipment Protection; H. E. Heddesheimer - AIEE Trans., Vol. 77, Feb. 1958, pp. 1225-30.

The position of plant engineer requires a working knowledge of many of the branches of engineering. Advancements in techniques, theory, and new concepts have "snowballed" in the past few years, and it becomes impossible for the operating engineer to read and to absorb the large amount of material available concerning his functions, and still continue his day-to-day duties.

To benefit best from the great amount of research and experimentation being done, it becomes necessary that a reference guide be prepared on subjects relating to the facility engineering function. In the General Electric Company, this is being done by the plant engineering and maintenance service.

Standards are not prepared, since individual components of the Company have distinct problems and procedures that do not lend themselves to one set of rules. The materials prepared are guides with which each operating component may establish their own standards by utilizing the portions applicable to their operation without the necessity of hours of research to find and assemble the most up-to-date techniques and developments available. The job is to keep these guides up to date and consistent with the latest and most applicable research.

With the foregoing remarks in mind, an example of this integration of knowledge into a usable form for the operating engineer is given. The general topic is "Grounding Techniques."

The Radio-Influence Characteristics of Bundle and Single Conductors -- 500-Kv Test Project of the American Gas and Electric Company; G. D. Lippert, S. C. Bartlett, W. E. Pakala, B. J. Sparlin - AIEE Trans., 1957, pt. 3, Feb. 1958, pp. 1302-1309.

This paper is in effect, a record of empirical (test) data relating different configurations of H.V. (500 kv) cables to production of radio noise, with emphasis on foul weather/fair weather observations.

Magnetic Shielding; W. L. Spring - Electrical Mfg., Vol. 61, pp. 138-139, 158, Feb., 1958.

Remarks on single and laminated mumetal shields, and on laminated upper and mumetal shields.

Electrical Measurements and Their Interpretation In Underground Cable Cor Problems; K. G. Compton - Corrosion, Vol. 14, No. 5, May 1958, pp. 237t-244t.

Methods of making duct surveys, surface potential gradient surveys, measurements of cable to reference electrode potentials, sheath current measurements and earth resistivity measurements are described. Examples are given of various types of measurement and their interpretation. It is pointed out that a single measurement of the potential between a cable sheath and a reference electrode in contact with nearby earth may not reveal the existence of a corrosive condition. Emphasis is given to the difference in polarity between self-produced corrosion cells and those resulting from external influences such as stray current or contact with a more noble metal. The importance of employing a variety of measurements in any particular study is shown. References are given to techniques employed by other workers in making underground corrosion tests.

Solderless Grounding for Braided Shields; F. C. March - Electronic Equipment Engrg., Vol. 6, June 1958, pp. 48-50.

Recent developments in solderless techniques for grounding and splicing of shielded and coaxial cables have aroused much interest. Navy and Signal Corps tests outlined here show that a major cause of equipment reliability problems may have been solved by these methods.

Welded Aluminum Conductors in Isolated Phase Bus; N. Swerdlow, K. N. Smith - Trans., AIEE., Vol. 77, pt III, June 1958, pp. 337-342.

This publication summarizes the experiences with welding of aluminum of several of the largest utilities in the country.

Earth Continuity Tester; Toop - Electrical Review, Vol. 163, July 4, 1958, pp. 25-26.

This article describes the constructional details and the operation of a portable earth continuity tester. The instrument measures the total impedance of the neutral/earth loop circuit; checks the effectiveness of the earthing conductor in flexible cords; and checks for correct installation of 3-pin general purpose outlets.

Designing Noise Free Enclosure Openings; A. L. Albin - Electronics, Vol. 31, Ref. sheet, Aug. 29, 1958.

Describes waveguide-beyond-cutoff openings for enclosures. Such openings may be required for meters, chapter, ventilation, or power leads.

Modernize Substation Grounding Practice; J. E. Hoopes - Electrical World, Vol. 150, Aug. 25, 1958, pp. 66-67.

This little article describes practical electrical grounding of chain link "vaults," fencing, gates, and gate posts, allegedly for safety to the public and company personnel during fault conditions on the "substation) system but, no doubt, for lightning too. Observations re cost reduction are made.

Improper Welding Systems Cause Corrosion; Capt. Palmer W. Roberts, Solomon Stemmer - Buships Journal, Vol. 7, Aug. 1958, pp. 7-8.

This brief article cautions against some dubious practices in welding returns that involve or may involve earth ground, notes some of the adverse effects, and makes recommendations for avoiding the problems.

A Study of Earth Currents Near a VLF Monopole Antenna With a Radial Wire Ground System; J. R. Wait - IRE Proc., Vol. 46, Aug. 1958, pp. 1539-41.

This article which is in the correspondence section of IRE Proc. presents a very brief theoretical derivation of the earth currents near a VLF monopole antenna with radial grounds. Also some experimental measurements are discussed which agree with the theory.

Measurement of Impedance and Attenuation of a Cable Through an Arbitrary Loss-Free Junction; J. Allison, F. A. Benson - IEE Proc., Vol. 105B, Sept. 1958, pp. 487-95

The paper considers the problem of finding the impedance and attenuation of a transmission line when measured through an arbitrary loss-free junction. Several possibilities for the exact determination of impedance in such a case are mentioned, and the results of tests carried out to determine the usefulness and accuracy of certain methods are presented. Some information is also given on the experimental accuracy of the well-known circle-diagram technique for determining transmission-line characteristics.

Any loss-free discontinuity between the measuring line and the cable will cause serious errors in the measured value of impedance, but the circle-diagram method still provides an accurate value for line attenuation. In this paper various possibilities for the exact determination of impedance when measured through a discontinuity are mentioned, and the results of experiments carried out to determine the usefulness and accuracy of some of the methods are presented. Information is also given on the experimental accuracy of the circle-diagram technique for determining cable characteristics, including the two-point method due to Blackband and Brown.

Voltage Gradients Through the Ground Under Fault Conditions; AIEE Working Group 66.1 Report - AIEE Trans., Vol. 77, Oct. 1958, pp. 669-692.

General information on present grounding practice, and many recommendations on grounding, are contained in the "Application Guide on Methods of Substation Grounding" presented in 1954 by a previous working group.

In 1956, the AIEE Substations Committee decided that this original application guide should be supplemented by a new report, covering in more detail one of the most important facets of the grounding problem as affecting safety, namely, the voltage gradients through the ground and along its surface under fault conditions. The present report is the result. Its intent is:

1. To establish, as a basis for design, the safe limits for potential differences which can exist in a station, under fault conditions, between points which can be contacted simultaneously by the human body.

2. To provide a step-by-step guide for the design of grounding systems, based on these limits.

3. To recommend test methods for obtaining data for design of ground systems, and for verifying the adequacy of ground systems as constructed.

4. To provide a comprehensive bibliography of existing literature on the subject for those seeking more detailed information.

In assembling information for this report, all bibliography references were studied and summaries were prepared. These may be further condensed and submitted for future publication. Translations of the principal French and German language references were also obtained or prepared by the working group.

<u>Concepts of Electromagnetic Interference Analysis and Control</u>; J. Berliner - Proc. 4th ARF Conf., pp. 387-411, Oct. 1958.

The problem of electromagnetic interference has multiplied rapidly in recent years because of the increase in the complexity and number of modern communications-electronic systems and equipments to meet ever increasing military requirements.

Interference may be defined as all radiated electromagnetic energy which will deteriorate the desired information, thus resulting in the degradation of military weapons capability.

Large numbers of high power transmitters, high gain antennas, highly sensitive receivers and other electronic equipments are operating close together because of real estate limitations as well as logistic considerations. This crowding, as well as the indiscriminate utilization of the frequency spectrum have added considerably to the overall problem.

This paper will describe the general concepts of a planned approach to resolve the problem. Examples will be presented of areas of accomplishment under the program at the Rome Air Development Center.

<u>Deep-Driven Transmission Grounds Reduce Lightning Outages</u>; J. M. Gillespie - Elec. Light and Power, Vol. 26, No. 20, Oct. 1958, pp. 47-9.

Statistics indicate that approximately two-thirds of all outages on lines operating at voltages of 100-kv and higher are caused by lightning. As a result, considerable time and effort is continually devoted to designing and constructing lines that will be practically free of outages due to lightning. Here is what Gulf Power has done to reduce these outages.

A Method for Controlling Airplane Wiring and Equipment Placement to Eliminate A-C Magnetic Field Interference; T. H. Herring - Proc. 4th ARF Conf., pp. 412-430, Oct. 1958.

This paper discusses a means of analyzing wiring interference situations in audio frequency airborne systems. It is noted that magnetic, not electrostatis, coupling is of importance, and that wire routing control is therefore necessary. The analysis makes possible this control and is based on simple model circuits whose parameters are chosen to simulate many different types of actual circuits. A Nomograph is described which can perform the necessary routing calculations quickly. Application problems are discussed.

Leakage of Electromagnetic Energy From Coaxial Cable Structures; K. Ikrath - Proc. 4th ARF Conf., pp. 311-357, Oct. 1958.

A better understanding of the behaviour of electromagnetic leakage fields emanating from braid shielded coaxial cables is obtained. It is shown that a braid surface EMF per unit length which is linked to the magnetic leakage-flux distribution in the braid apertures tends to support a slowly propagating surface wave along the cable. At higher frequencies end effects play an important role in the shaping of the leakage radiation fields which acquire the typical tilted multilobe patterns of slow wave radiators.

Radio Interference Problems at AFMTC Cape Canaveral, Florida; C. W. North - Proc. 4th ARF Conf. --. 26-38, Oct. 1958.

The paper discusses radio interference problems for orientation of administrative and supervisory personnel. It will be well illustrated with slides of various interference situations with a verbal description of each interference problem, including communications transmitters and receivers, broadcast stations, airports, teletype, radar and loran, sonar and ultra-sonics, rotating electrical equipment, and many others.

A-Free-Space Method for Measuring Coaxial Cable Shielding Effectiveness; R. F. Robl, E. P. Schatz - Proc. 4th ARF Conf., pp. 372-386, Oct. 1958.

This paper describes a free-space method for determining the relative shielding effectiveness of coaxial cables. The leakage fields from a short-circuited coaxial cable radiating as a monopole antenna above a ground plane are measured and then compared with the results of a theoretical analysis which considers the radiation due to a current source having the same distribution as the current within the coaxial

cable. A shielding Effectiveness Factor is defined and given for a number of coaxial cables for a frequency of 350 megacycles.

<u>Corrosion</u>; D. G. Anderson - J. of Electronics and Control, Vol. 5, Nov. 1958, pp. 443-56.

The financial loss incurred as a result of the corrosion of metals represents quite a substantial part of the national income. The following paper gives a brief general survey of the main causes of corrosion in industry and outlines the more important methods of protecting against corrosive environments.

The paper is by no means intended to be an exhaustive treatise on this vast subject; its primary object is to point out some of the more obvious pitfalls to be avoided and to assist those engaged in production processes who may not be familiar with electrochemical phenomena.

<u>Silver-Plated Aluminum Bus Conductor</u>; C. E. Burley - AIEE Trans. III, Vol. 77, Dec. 1958, pp. 1024-8.

This paper briefly discusses the advantages of silver plated aluminum bus bars, techniques of silver plating aluminum and electrical tests and corrosion properties of these bus bars.

<u>Shielding in Modern Computer Design</u>; C. M. Jorgenson - Automatic Control, pp. 46-50, Dec., 1958.

As computer pulse rate increases, wavelengths approach cabinet dimensions.

<u>Grounding of Power Station 4,160 Volt Auxiliary Systems</u>; T. H. McGreer - AIEE Trans., Vol. 76, Feb. 1958, pp. 1459-63.

As the size of power station units has increased, it has become economical to raise the voltage on auxiliary systems to 4,160 volts. Almost universally, 2,400-volt systems have been operated ungrounded. With the higher voltage, the question again arises whether the system should be grounded and if so, whether there should be neutral impedance. It is apropos then to enumerate the advantages and disadvantages of each mode of operation and then select the one that appears most justified for power station auxiliary supply. An exact answer cannot be expected; the probabilities can be weighed and the best possible decision made.

To simplify the study, the question is divided into two parts: a comparison between grounded and ungrounded systems, and a discussion as to what mode of grounding is best suited to the problem. For the sake of completeness, a discussion of resistor rating and the type and performance of ground relays is included.

Evaluation of Solderless Wrapped Connections for Central Office Use; S. J. Elliott - AIEE Trans. I, Vol. 78, May, 1959, pp. 185-94.

This paper discusses the advantages and limitations of solderless wrapped connections. This paper is specifically related to telephone central office use, but the results should be valid anywhere. Also described is an experimental analysis of these connections and the results of this analysis.

Buried Cable Radiation Studies; A. A. Carterette, S. Weintraub - Cooke Engineering Co., Contract NBy 17827, Navy Dept. Bureau of Yards and Docks, July 17, 1959, AD 275390.

Criteria for measuring and suppressing EMI from underground cables are given. Studies have shown that a high degree of attenuation of EM energy injected into a cable which is properly buried in a trench subsequently filled with alternate layers of coke and anthracite coal will be obtained. Recommendations for improving the sensitivity of instruments used to measure EMI are made.

Earth Currents Near a Top-Loaded Monopole Antenna With Special Regard to Electrically Small L-and T-Antennas; H. Lottrup Knudsen - National Bureau of Standards, Journal of Research, Vol. 62, No. 6, Research Paper 2961, June 1959, pp. 283-96.

An investigation has been made of the ground currents near a top-loaded monopole with nonazimuthal symmetry. Formulas have been developed for the surface current density produced by an inclined, straight wire over a horizontal ground plane for an artibrary current distribution on the antenna. Working formulas have been developed and numerical calculations of the surface current density on the ground plane have been carried out for the case of a small antenna with a linear current distribution. These results have been used for the calculation of the contribution to the surface current density due to the top loading in the case of an L-antenna and in the case of a T-antenna. In each case both the absolute value of the surface current density arising from the top loading and the relative value of its component have been plotted, as it may be expected that this component under certain circumstances

may be important in calculating the ground losses in the case of a system of radial ground wires.

Contiguous Wrapping of Transmission Line Conductors With High-Mu Tape for Large Radio-Interference Attenuation; Clark and Hitchcock - Proc. 5th ARF Conf., pp. 560-577, Oct. 1959.

This paper describes the application of a high-permeability SiFeMg tape to a transmission line, resulting in high attenuation of radio-frequency energy in the range of interference frequencies found normally on transmission lines. A theoretical treatment is presented of a long conductor coated with a high-permeability material. The results of this analysis show a great magnification of the skin effect losses at frequencies above the power transmission frequency, and are supported by experimental measurements made on three long conductors wrapped with a thin, high-permeability tape. A small helical air gap was formed in the wrapping of two of the transmission lines to reduce saturation effects which would normally occur on lines distributing power. The attenuation measured on these lines was about half that of the fully wrapped line, but gave much lower standing wave ratios and a low characteristic impedance phase shift. The attenuation of these lines was large compared to the attenuation of a bare line.

It is expected that high-permeability tape coatings with a gap will prove to be a useful and practical technique for reducing interference on power transmission lines.

Investigation of Corona Noise in a Three-Phase Transmission Line; J. e. Diamessis - Proc. 5th ARF Conf., pp. 247-283, Oct. 1959.

This paper reports on an experimental study of the noise characteristics of corona discharges generated in a laboratory model of a three-phase transmission line. Measurements were made of the noise radiated from the model and the corona current in a conducting element placed near the model transmission system. The measurements have to some extent followed a standard practice, and to some extent are new in the study of interference. The significant data collected, the model employed and the measuring techniques used will be described in detail.

A Method of Evaluating the Effectiveness of Radio-Frequency Gasket Materials; T. M. Good - Proc. 5th ARF Conf., pp. 601-721, Oct. 1959.

This paper is concerned with describing a method for evaluating the effectiveness of radio-frequency gasket materials. The effectiveness which we are talking about is the ability of the gasket materials to suppress electromagnetic interference fields in the frequency range of 0.15 to 1,000 mc. The paper not only presents actual test setups and test results which were used and obtained, but also discusses the problems encountered and their solutions. Some of these solutions were actually used in the testing and others are ones which are suggested for future work in this field.

Controlling Magnetic Field Interference in Wiring; T. H. Herring - Elect. Manuf., Oct. 1959, pp. 127-9.

Electrostatic pickup in complicated wiring systems can be relatively easily controlled by proper shielding. Pickup from magnetic fields, however, is not so readily prevented. Proper routing of circuits is the most logical and effective way of controlling this detriment to accurate operation of systems involving precise, low-level sensitive circuits, such as those found in large airplanes. The determination of the proper spacing in this routing is the design engineer's problem and analysis of the circuits using a convenient nomograph can help him solve it.

New Techniques for Evaluating the Performance of Shielded Enclosures; D. P. Kanellakos, R. B. Schulz, L. C. Peach and A. P. Massey - Proc. 5th ARF Conf., pp. 526-559, Oct. 1959.

New improved and simplified techniques for measuring the effectiveness of shielded enclosures between 14 kc and 10 kmc are presented. It is shown that tests at three frequencies, i.e., at approximately 15 kc, at the lowest natural resonant frequency of the enclosure, and near 9 kmc, are necessary for evaluating the performance of shielded enclosures.

A Method of Measuring High Power Transmitter Cabinet and External Wiring Radiation; V. J. Mancino - Proc. 5th ARF Conf., pp. 342-354, Oct. 1959.

This paper describes a method for measuring radiated interference from large transmitters without the necessity of placing the transmitter either in an open field or a shielded room. This method utilizes a substitution technique. Therefore, it can be used in any location where measurements can be made conveniently regardless of the local topography because the path loss is automatically compensated for. The choice of a suitable site for the location of the transmitter is limited principally by the availability of sufficiently remote points which lie in the

distant or radiation field. This method was developed primarily for TV Transmitters, but is applicable for use with any high power transmitter.

Test data is provided along with the sample calculations for the harmonic radiations of a 2 KW transmitter. Three series of measurements were made over a three month period in order to verify correlation. In addition, the variation of path loss with frequency over a fixed distance was determined each time for each frequency.

<u>Radio Noise Testing of the Lockheed Electra</u>; D. R. Meyer, D. S. Davis - Proc. 5th ARF Conf., pp. 163-178, Oct. 1959.

The avionics Group of Lockheed's Flight Test Division has conducted and is continuing to conduct radio interference surveys on the many varied airline configurations of the Electra Prop-jet aircraft. These tests are performed in the spirt of MIL-I-6051. During the course of these tests many interesting and perplexing radio noise problems have arisen, virtually all of which have been resolved at the present time.

The aircraft's electrical power system is all AC, using two transformer-rectifiers to produce all needed DC power. These full-wave, six-phase rectifiers are the principal noise producing sources aboard the aircraft. This paper will deal with the methods used in combating the effects of these and other radio noise sources associated with the Electra, together with comments on special radio noise problems which arose because of ground-loop conditions, insufficient bonding, and by direct conduction or radiation of RF energy.

<u>Design of a Wire Communication System in a Shielded Passageway of the BMEWS Radar System</u>; H. G. Schwarz - Proc. 5th ARF Conf., pp. 398-407, Oct. 1959.

The paper discusses the preventive measures which can be taken in the planning stage of a large radar system to minimize interference on data and voice communication links. Calculations and model measurements to determine the expected interference level from the power system will be treated in detail.

<u>Fields in Electrically Short Ground Systems: An Experimental Study</u>; A. N. Smith, T. E. Devaney - Journal of Research of the National Bureau of Standards - D. Radio Propagation Vol. 63D, No. 2, Sept.-Oct. 1959, pp. 175-80.

An experimental study of magnetic field distribution in a simplified radial ground system on poorly conducting soil under an electrically short, toploaded monopole is described. It is shown that the distribution is that expected from the theory of J. R. Wait in those portions of the radial system satisfying the assumptions of the theory, and that the theory may still be successfully applied for H-field power loss computations even when this is not fully the case. The particular model system studied exhibits a condition suggesting damped standing waves on the radials in the area where the radial spacing exceeds that required by the theory.

Planning Interference-Free Communications-Electronics Systems; A. H. Sullivan, Jr. - Proc. 5th ARF Conf. pp. 408-416, Oct. 1959.

The basic concept of planning and engineering interference free communcations-electronics systems is discussed and a step-by-step planning procedure is shown. What commanders should know about the threat of interference to weapons systems is considered. Some comments are presented on MIL-I-26600 (USAF). The economics of pre-engineering systems for minimum interference is briefly discussed and compared with the cost of suppressing and reducing interference after system installation. It is suggested that the procedures of "value engineering" be applied.

Design of Electromagnetic Interference Reduction Using Computer Simulation Techniques; D. R. J. White, R. Marcus - Proc. 5th ARF Conf., pp. 121-162, Oct. 1959.

A digital computer simulation approach to the prediction of electromagnetic interference situations is described. Representative mathematical models of transmitter and receiver characteristics, environment scenarios, propagation phenomena and terrain effects, and signal acceptability criteria are presented in graphical and tabular form. Value judgments are used to score and evaluate calculated performance in light of defined objectives. Anticipated results of recommended system changes are computed and quantitatively compared until a sound system design which adequately reduces interference to and by communications-electronic systems is obtained.

Design and Analysis of an Unplated High-Pressure Limited-Area Bolted Electric Joint: A Method of Calculating Various Components of Joint Resistance; R. K. Allen - AIEE Trans. III, Vol. 76, Dec. 1959, pp. 1047-53.

Film resistance may be controlled by the use of noble metal platings to render the conductor surfaces inert, or by designing the joint geometry to obtain a scrubbing action under pressure when the joint is made up. This paper presents a joint design that utilizes the latter method of control and discusses a means of predicting joint performance by calculating values of the components of total joint resistance for various designs.

Study and Evaluation of Radio Frequency Grounding Systems; Interference Testing and Research Laboratory, Inc., Boston, Massachusetts, Contract No. NBy-17828, 1960.

Objective: Determine if NEC-type grounding systems could eliminate unwanted RF emissions.

Finding: NEC grounding reduces unwanted emissions only 40 to 60 dB. Literature survey (30 Hz to 3 GHz) revealed no standards and no theory. on which to base RF grounding system design. Electromagnetic interference control (EIC) techniques are outlined. Foreign sources favor shielding.

Electromagnetic Interference and Vulnerability Reduction; J. J. Egli - Army Signal Research and Development Lab., Fort Monmouth, N.J., 1960, 6p. incl. illus., Unclassified Report, ASTIA AD-214 740.

Interference and vulnerability, the first signifying a mutual or unintentional interference, and the second signifying an intentional interference are omnipresent disturbances which must be reduced to permit tactics of the military to be consummated without extraneous impairment. In the research and development area of electromagnetic interference and vulnerability reduction, three important phases are essential to achieve reduction: (1) theoretical analysis, (2) design criteria, and (3) instrumentation and measurements. A research and development organization capable of handling these three important phases was established at the U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J. (Author)

The Effect of Elevated Temperature on Flash-Welded Aluminum-Copper Joints; C. R. Dixon, F. G. Nelson - AIEE Trans., III, Vol. 78, Jan. 1960, pp. 491-5.

This article describes tests performed to evaluate the effects of elevated temperatures on flash-welded aluminum-copper joints made using the present (1959) improved techniques (of flash welding). From tests

of almost 500 joints, the effects of heating on tensile strength, ductility, resistance to impact, and electrical resistance are determined.

RFI Gasketing; O. P. Schreiber - Electronic Design, Vol. 8, No. 4, pp. 46-49, Feb. 17, 1960.

To reduce RFI leakage in equipment, all seams, joints, and openings must be sealed tight. Various schemes are discussed and practical methods of selecting materials and gaskets are outlined.

The Effect of Electrical Grounding Systems on Underground Corrosion and Cathodic Protection; B. Husock - AIEE Trans., Mar. 1960, pp. 5-10.

The essential purpose of most electrical grounds is protection. The National Electrical Code states that: "Circuits are grounded for the purpose of limiting the voltage upon the circuit which might otherwise occur through exposure to lightning or other voltages higher than that for which the circuit is designed: or to limit the maximum potential to ground due to normal voltage." It states further that exposed metal enclosing electric conductors or enclosing electric equipment are grounded for the purpose of preventing a potential above ground on those enclosures. While there are other purposes for electrical ground, such as those which are required in the communications field, most grounding is done for protection either of equipment or of personnel. Even static grounding at oil or gasoline unloading facilities is a protective device.

Practical Approach to Interference Prediction and Suppression; Paul B. Wilson, Jr., - Electronics, Vol. 33, No. 37, pp. 84-87, Sept. 9, 1960.

Information is provided on circuit interference problems and on proper grounding techniques to aid in system design. This article presents methods of estimating interference and preventing it. The problem is examined first considering circuit cards, then sub-assemblies, then the combining of sub-assemblies into system packages.

Radio Frequency Shielding Properties of Metal Honeycomb Materials and of Wire-Mesh Enclosures; D. J. Angelakos - Proc. 6th ARF Conf., pp. 265-280, Oct. 1960.

For many of the structures used to shield against interfering signals, it is possible to estimate the lower limit of the amount of shielding for low and high frequency signals.

This first part of the paper (Part A) describes means of estimating the high-frequency limit of shielding above which frequency any open cell structure may pass the interfering signal. The cells act as equivalent waveguide sections. The low-frequency limit is determined by considering the structure as having an equivalent mass or an equivalent conductivity. Certain statements can be made and a shielding factor can be estimated for the intermediate frequency range.

The analysis has been applied to the metal honeycomb material ("Haxcel") and effective shielding factors have been obtained for both the electric and magnetic fields.

In the second part of the paper (Part B) the shielding properties of perforated metal sheets and of wire meshes are obtained.

<u>The Shielded Test Cells of the Titan ICBM Test Facility, the Martin Co's Denver Division</u>; A. R. Kall, F. Kugler - Proc. 6th ARF Conf., pp. 295-304, Oct. 1960.

The vertical test facility at the Martin Company's Denver Division, is used for production and engineering testing of the Titan ICBM. It consists of 9 vertical cells, each over 100 feet high, six of which are electromagnetically shielded. The shielding requirements were the most severe encountered by this company to date.

The paper will describe architectual and constructional details of the shielded cells, together with electronic shielding design. Quality control inspection methods on the permeability of the shielding material, method of welding the shielding material, installation of waveguide air inlets, power and signal filters, etc., are discussed. The testing of the shielding effectiveness was interesting and consisted in part of novel procedures, including the testing of all accessible welded seams, all breakthroughs in the shielding (structural I-beams, utility conduits, etc.), and the shielded entrance doors.

The electrical operational requirements were bilateral: prevention of r-f emission from inside the cell into the surrounding ambient, and prevention of external high-level interference from interfering with sensitive electronic experimentation inside the cell.

Radio Frequency Interference analysis and Reduction in a Complex Radar Trainer System; F. Kugler, E. S. Warchaizer - Proc. 6th ARF Conf., pp. 224-236, Oct. 1960.

The problems associated with radio interference testing of a piece of military equipment are multiplied many fold when this equipment comprises a system rather than a single unit. This paper intends to show some of the problems encountered and how they were solved when a Radar Trainer was tested to a Military Specification on Radio Interference. The entire course of the testing program is described, from the preliminary radio interference studies, before the system was actually built, to the testing of the preproduction unit and finally the actual production testing. This paper will point out the necessity for a radio interference design criteria in the early stages of design for any complex electronic system.

Evaluation of Conductive Glass in Fluorescent Light Shielding Application: H. M. Sachs, H. G. Tobin - Proc. 6th ARF Conf., pp. 281-294, Oct. 1960.

Comparisons were made between the shielding properties of conductive glass of various resistance coatings, and copper screening, hardware cloth, and an aluminum grill as used in a fluorescent lighting fixture. The results are tabulated.

In addition, a determination has been made of the ability of a fixture in which the materials are installed to meet the limits of radiated interference as specified in MIL-I-16910A. The grounding procedure required to meet this specification in the case of coated glass has also been determined.

A plane wave analysis of the coated glass has also been made. A correlation between the resistance of the coating used and the shielding effectiveness of the glass has been determined.

The Shielding Effectiveness of Concentric, High Frequency Transmission Lir E. T. Pfund, Jr., J. E. Russell, Capt. Bard Suverkrop - Proc. 6th ARF Conf., pp. 360-371, Oct. 1960.

The relative shielding effectiveness of several concentric lines has been experimentally determined. Relative interference considerations for standard and corrugated tubing of copper, aluminum, nickel-plated copper, stainless-clad copper, and stainless-clad coin silver are presented for ceramic plastic, and air-insulated transmission lines from 150kc to 28mc/s.

ICBM Checkout Equipment Errors Due to Interference; B. Weinbaum - Proc. 6th ARF Conf., pp. 237-255, Oct. 1960.

To achieve an ICBM launch capability of 15 min. or less, it is necessary to utilize automatic programmed checkout equipment. This equipment monitors missile and launch control subsystems and prints out "go" and "no-go" information derived from analog data accepted through a bandwidth of 30-10,000 cps. Random "no-go's" and low-precision behavior result unless interference control is exercised to optimize stistical evaluation, in terms of signal-to-noise ratios, of optimum bonding and grounding configurations. Owing to the large size of the launch complex, a multipoint grounding configuration and uniform treatment of cable shields is the most feasible approach to optimizing signal-to-noise ratios.

One-Point Ground System With R-F Shielding and Filtering; R. A. Varone - Electrical Engineering, Dec. 1960, pp. 1028-33.

An organized plan for handling the problem of grounding, shielding and filtering the electronic system for missiles and ground support equipment is presented. The result is a one-point ground for the complete system, with all ground loops open.

Solid Aluminium Cables Part 2 - Installation and Jointing; Electrical Times, Vol. 139, Jan. 26, 1961, pp. 125-9.

This paper discusses the advantages, the installation and jointing techniques of "Solidal" solid aluminium cables. A step-by-step jointing procedure is presented.

Designing for Low Level Inputs D. B.Schneider - Electronic Industries, Vol. 20, Jan. 1961, pp. 81-5.

The problems of low level input instrumentation have mushroomed with the missile era. Not only is the new terminology defined in this article but also positive suggestions are offered to eliminate the systems engineering problems involved.

Studies of EMC of Equipment and Systems; F. Haber, D. E. Mode - Moore School of Electrical Engineering, U. of Pennsylvania, Philadelphia, Pa., Quarterly progress report, no. 1, Nov. 1, 1960 - Jan. 31, 1961, Feb. 28, 1961, 72p.

The work on simulation of power line corona noise by means of a pulse modulated Gaussian noise was completed. A method for selecting parameters for the simulator is presented. Procedures for inter-comparing noise meter readings obtained on so-called direct-reading peak and quasi-peak detectors are made. In order to make such comparisons, it is necessary to know the nature of the noise source. A detailed discussion of the approach used to analyze and evaluate noise in underwater communications systems is presented. Models are included of the possible sources and means of propagation. It is believed that one of the major factors in such systems is the transfer of electromagnetic energy with the hull to critical positions immediately outside the hull.

Quiet Wiring; W. Morton - Electro-Tech., Vol. 67, No. 3, pp. 78-81, Mar., 1961.

Increasing demands for accuracy and sensitivity are being placed on today's instruments and systems. Often the circuits carrying signals which are responsible for this accuracy and sensitivity must operate in disturbing electromagnetic ambients. These circuits must be "quiet" despite such disturbances.

X-Rays Show Condition of Terminations; T. L. Bourbonnais - Electrical World, Vol. 156, July 17, 1961, pp. 46-7.

This brief article basically states that x-rays are being used to find good workmanship or incipient weakness in materials or methods with non-destructive inspection and analysis.

Evaluation of Interference Suppression of Fluorescent Lamps; D. B. Clark - Naval Civil Engineering Lab., Port Hueneme, Cal9fornia, Final Report, Oct. 6, 1961.

The evaluation of the interference characteristics of commercial fluorescent fixtures advertised as interference-free, including both hot-cathode and cold-cathode lamps, demonstrates that those fixtures which are completely enclosed electrically are free of interference. A hot-cathode instant-start fixture, with conducting-glass door panel, interchangeable with an aluminum honeycomb door panel covering a one-piece metal fixture proved to be greater than 6 db below the specification limits shown in BuShips MIL-I-16910(A). The cold-cathode lamps tested failed to meet specification limits. An enclosed fixture which failed to pass specification tests was modified by electrically bonding at all junctures at approximately 2-inch intervals, including

the 2-inch by 2-inch by 1-3/8-inch-deep grill. By this means interference was reduced to an acceptable level. Light emission from the interference-free commercial fixture was measured, and the conducting-glass panel and the honeycomb aluminum panel caused a loss of approximately 10%. Replacement of the nonconducting panel-closure gaskets with radio-frequency-suppressing gasket stripping, resulted in an average reduction of 7 db in the magnetic induction field.

<u>Irradiation Susceptibility Nomograph</u>; Fred Kugler, Albert R. Kall - Electronics, Vol. 34, No. 41, pp. 68-72, Oct. 13, 1961.

This article presents a nomograph which may be used to determine interference-susceptibility in complex electronic systems. Its use is demonstrated by an example.

<u>Field Evaluation of the NCEL Interference-Attenuating Power Conductor</u>; D. B. Clark, J. L. Brooks - Proc. 7th ARF Conf., pp. 662-708, Nov. 1961.

The field evaluation of a 4.0 mile installation of 13.2 KV, 3-phase, power distribution wires replaced with special interference-attenuating conductor developed at the U.S. Naval Civil Engineering Laboratory was completed in January 1961. The power line, wrapped with high-permeability tape was tested at the U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona. NCEL engineers and technicians made survey measurements of the broad-spectrum electromagnetic interference (30 cycles per second to 1,000 megacycles) induced at the end of the line with large-impulse noise generators. The special line, with large magnitudes of interference at its beginning is shown to attenuate effectively over the broad frequency spectrum to bring the noise level of the line down to the level of the natural ambient in about half the length of the line. A 30-kw load placed on the power line did not make any measurable change in its attenuating properties.

<u>Shielding Efficiency Calculation Methods for Screening, Waveguide Ventilat Panels, and Other Perforated Electromagnetic Shields</u>; W. Jarva - Proc. 7th ARF Conf., pp. 478-498, Nov. 1961.

The basic procedures for calculating the shielding efficiency of continuous metallic shields, which were originally developed by S. A. Shelkunoff, have been found to apply equally as well to perforated shields. Methods are developed for calculating the shielding to be expected from discontinuous shields having a wide range of different physical structures, and results are compared with values measured in the laboratory. Theoretical explanations are provided for test results

obtained by some investigators, which are essentially independent of frequency, whereas results obtained by others vary radically with frequency. The methods provide means for determining the polarizability of rectangular openings and also permit computation of the difference in shielding measurements obtained with antennas placed close to or far from the shielding barrier.

Requirements of Measurements of Shielded Installations; R. G. Klouda - Proc. 7th ARF Conf., pp. 460-472, Nov. 1961.

This paper delves into the various practical requirements of shielded installations and how measurements are made under field conditions. Discussions will range from large built-in installations on military sites to prefabricated types of enclosures. The usefulness of various materials used in shielded installations over a given frequency range will be listed so that a handy reference may be had when a shielding requirement comes up. In the past a compromise between shielding effectiveness and building construction has limited to some extent the usefulness of the shielding. New ideas and techniques will be offered to enhance the shielding effectiveness for these installations.

An Integrated Approach to Bonding, Grounding and Cable Selection; T. M. Newman, A. L. Albin - Proc. 7th ARF Conf., pp. 434-459, Nov. 1961.

There appears to be considerable confusion over the methods and philosophies of grounding, bonding, and cable treatment which will result in optimum interference reduction. This paper presents means to minimize interference through the proper selection and utilization of various cables, the establishment of a well-bonded ground plane, and the implementation of good bonding techniques, considered from the viewpoint of integrated system requirements.

Bonding and grounding philosophies and the method of inter-connecting equipment racks, cabinets, and instrumentation were investigated. The mechanical and electrical details for establishing a low impedance bond were also studied.

The establishment of a ground plane was required in order to realize the full benefits in reduction of r-f interference coupling and audio crosstalk. The relative advantages of single point and multipoint grounding philosophies will be shown for radio- and audio-frequency applications. The use of a multipoint ground system was recommended in most cases because of its superior advantages for r-f interference control.

Earth Resistivity Measurements for Grounding Grids; Allen L. Kinyon - Trans. AIEE III, Vol. 80, Dec. 1961, pp. 795-800.

Comprehensive grounding grid resistivity surveys have been conducted on the Bonneville Power Administration system since 1959. In addition to the scheduled surveys at proposed substation sites, resistivity measurements have been made periodically at two experimental test areas. A description of these surveys and tests and a discussion of the results are presented.

Applying Shielded Cables to Reduce Interference; Arnold L. Albin - Electronic Design, Vol. 10, No. 1, pp. 48-51, Jan. 4, 1962.

Interference in electronic equipment can be less of a problem if cable shields are used effectively. Here are some points to keep in mind when designing inter-connecting cabling.

Pressure-Type Connectors for Aluminum and Copper Conductors; N. Shackman, R. W. Thomas - Trans. AIEE III, Vol. 80, Feb. 1962, pp. 991-5.

A study of the connection to aluminum conductor indicates that high pressures are required to effect a satisfactory connection and that relative movement between strands during tightening greatly assists in reducing contact resistance. A properly designed connector will incorporate means for applying high pressures with considerable distortion of the conductor. Heat-cycling tests which included mechanical stressing were found to be valuable in comparing designs. An aluminum-bodied connector with an aluminum screw gave satisfactory performance with both copper and aluminum conductors.

Interference Measurement Technique; C. L. Neal - General Dynamics/Astronautics, San Diego, California, Final Report, July 1960-Dec. 1961, April 1962.

The purpose of this program was to develop improved techniques for measuring electromagnetic interference (EMI). Existing techniques were investigated with a view to improving the interference measurement requirements of MIL-I-26600, "Interference Control Requirements, Aeronautical Equipment." Conducted and radiated measurement techniques were considered.

It was found that better control and standardization of test conditions could be achieved for more meaningful and repeatable test data. Methods were investigated toward reducing measurement cost and time. Techniques

suggested toward this end included modifying methods for using EMI receivers and eliminating superfluous and/or redundant data taking.

An investigation was made into the application of a method for measuring the impedance of a closed series loop to measuring conducted interference. Areas are recommended for further investigation.

<u>Studies of Electromagnetic Compatibility of Equipment and Systems</u>; F. Haber, J. Goldhirsh - Moore School of Electrical Engineering, University of Pennsylvania, Quarterly Progress Report No. 5, 1961.

An investigation of the shielding efficiency of cylindrical shield enclosing a two wire line is made. In particular, the shielding efficiency expression is derived, and corresponding curves have been prepared, indicating the shielding effectiveness of different material as a formation of frequency.

<u>A Survey of Interference Reduction Technique</u>; A. M. Brogdon, J. C. Cook, C. F. Douds - HRB-Singer, Inc., State College, Pennsylvania, 289.3-F Vol. 1, AF 30 (602) - 2445, Applied Research Branch EM Vulnerability Lab, RADC-TDR-62-84, Vol. 1, June 15, 1962.

Fundamental concepts of interference reduction for communication and radar transmitters and receivers are presented. Consideration is given to interference suppression in communication transmitter and high power radar transmitters. The problem of properly specifying high-power microwave filters is given particular attention. Shielding design is summarized with formulas and tables.

<u>The Protection of Houses By Lightning Conductors - An Historical Review</u>; D. Muller-Hillebrand - Journal of the Franklin Institute, Vol. 274, No. 1, July 1962, pp. 34-54.

A review of the research work on lightning conductors is presented from 1750 through 1960. On the basis of recent work, it is concluded that small houses may be economically protected from lightning damage.

<u>Development of New RF Attenuation Devices</u>; D. G. Tailleus, R. L. Langston - AMC, Redstone Arsenal, Huntsville, Alabama, July 26, 1962.

The results are presented from radio-frequency attenuation tests of six shielding devices installed on a personnel door of a radio-frequency

shielded room. The shipboard-type, watertight hatch, personnel door was modified for use in these tests by installing a channel around the door periphery and a channel around the door frame for insertion of the RF barrier device. Of the six RF barrier devices tested, a copper mesh material provided the highest RF attenuation.

How the System Manager Should Approach the Problem of RFI; Joseph H. Vogelman - Electronic Design, Vol. 10, No. 17, pp. 58-61, Aug. 16, 1962.

If a step-by-step program for controlling RFI is not begun early in the design of an electronic system, the system eventually may have to be redesigned or put through costly RFI testing. The system manager should try as early as possible to predict the interference sources, sinks, worst-case magnitudes and the frequencies at which they will occur.

Military Specifications for RFI-Their Requirements and Test Procedures; Albert R. Kall, E. Stanley Warchaizer - Electronic Design, Vol. 10, No. 20, pp. 52-61, Sept. 27, 1962.

Military specs on RFI reflect the impact of closely crowded RF environments found in complex weapons and communication systems. Authors Kall and Warchaizer, veterans of RFI warfare, offer a compact summary of current specs to clarify military requirements.

Designing and Applying RFI Shields and Gaskets; O. P. Schreiber - Electronic Design, Vol. 10, No. 20, p. 62, Sept. 27, 1962.

Shielding can be used to contain radiating interference at its source or to exclude it from susceptible equipment. Factors involved in the design of shielding and techniques for sealing openings in shields are discussed.

Preliminary Measurements Related to Procedures for Measuring Systems Susceptibility; G. Barker, E. Gray, R. M. Showers - 8th Tri-Service Conf. on EM Compatibility, pp. 218-240, Oct. 1962.

Theoretical considerations of methods for evaluation of systems susceptibility below 15 kc were recently described. The methods included tests of components and interconnecting cables with regard to their susceptibility to voltages, currents and fields. Cable susceptibility to magnetic fields is measured by means of loops, and the effectiveness of shields and balancing techniques can be evaluated with

the use of a toroid. The application of these methods to a specific electronic system has recently been made. Practical considerations have shown the conditions under which certain of the tests described were particularly valuable. In this paper there will be described specific results obtained in the laboratory and on an installation, interpretation of the results, and limitations on the techniques.

The Shielding Effectiveness of a Conducting Plane; W. T. Cronenwett - IRE Trans., PGRFI, Vol. RFI-4, No. 3, p. 17, Oct. 1962.

In applications where a power distribution conductor carrying a large current is routed near a conducting metal wall or chassis, voltage will be induced in circuits "grounded" to the opposite side of the wall. The effectiveness of the wall in shielding the grounded circuits from the power circuit is a function of conductor distance from the wall, the current and frequency carried by the conductor, and the conductivity, permeability, and thickness of the wall.

Maxwell's equations are solved for the case of a conductor parallel to a metal plane and the shielding effectiveness is expressed as the ratio of two integral equations. The expression is evaluated numerically by digital computer and is presented as sets of curves for appropriate values of the independent variables.

Shield Termination Prediction Method H. W. Ervin - Proc. 8th Tri-Service EM Compatibility Conf., pp. 691-711, Oct. 1962.

Shielding is one means of reducing electromagnetic coupling between adjacent conductors. Magnetic field attenuation is primarily a function of shield permeability and thickness and is independent of the technique used to terminate the shield. Various shield termination techniques have definite advantages and disadvantages in the reduction of electric field coupling between adjacent conductors. Parameters such as ground impedance, distributed conductor impedance (both inherent and self-induced), distributed coupling capacitance, source and load impedance, bonding impedance, and the frequencies of signals being transmitted, are the basic factors which determine the compatibility of a shield termination technique to a specific conductor configuration. Simplified equivalent circuits and potential decay diagrams are used to predict the most compatible shield termination technique for various conductor configuratios with a small length of line-to-wave length ration. Unusual aspects of shield termination techniques are explained by using this prediction method.

The Grounding of Electronic Equipment; Rocco F. Ficcki - 8th Tri-Service Conf. on EM Compatibility, pp. 643-669, Oct. 1962.

The problem of the grounding of electronic equipment is quite complicated. Safety, which is the prime consideration in the grounding of electrical equipment, becomes secondary, because in electronic equipment, while it is still important that it be able to be operated within the limits of safety, the deleterious effects of ground currents must be minimized if the equipment is to be operated at all.

A number of different grounds are discussed:

Mechanical, electrical and three types of typical grounding techniques are used in connection with electronic equipment: multi-point, floating and single point systems.

Implementation of Bonding Practices in Existing Structures; Donald R. Lightner, James C. Toler - Proc. 8th Tri-Service Conf. on EM Compatibility, pp. 670-690, Oct. 1962.

Many problems are encountered when attempting to provide satisfactory bonding techniques in structures that already exist. Many of the facilities presently used to check out complex space vehicle systems were constructed without considering the bonding requirements. With the increased interest in digital checkout equipments, the bonding requirement of checkout facilities will become more stringent in the future.

This paper will present the procedures and techniques being implemented to establish, insofar as practical, that all permanently installed metallic devices are directly bonded to an existing structure. After this task is completed, an equipment user will be able to connect to a common ground at any location in the facility. Information will be provided on bonding hardware and methods. Additional information will include the detailed measurements being made to obtain quality assurance provisions.

The effectiveness of each bond connection will be determined by DC resistance measurements. The justification of using a DC resistance measurement in lieu of RF impedance measurements will be discussed.

Information will be included for using a specific thickness of copper for the bond strap. A family of charts will be provided that present the AC/DC resistance as a function of frequency for assorted strap thickness.

Examples will be included where standard bonding practices could not be implemented, and other approaches were required to provide a satisfactory bond connection.

Case and Cable Shielding, Bonding, and Grounding Considerations in Electromagnetic Interference; C. B. Pearlston - IRE Trans., PGRFI, Vol. RFI-4, No. 3, p. 1, Oct. 1962.

Some of the basic techniques in electromagnetic interference reduction are those of bonding, grounding, and shielding. Often, the proper techniques are employed without a full understanding of the rationale behind the techniques, and often the theory is understood but imperfectly put into practice. This turorial paper attempts to assemble concisely the theory and techniques relating to shielding, bonding, grounding, and cable selection.

Proving the Adequacy of Station Grounds; A. Elek - AIEE Trans., I, Vol. 81, Nov. 1962, pp. 368-76.

The definition of ground resistance and ground impedance in the case of alternating currents is discussed. Ground resistance measurements with earth testers are compared with power frequency methods and the errors associated with the location of auxiliary grounds are described. It is emphasized that the ultimate purpose of testing station grounds is to determine touch voltages and potentials arising on communication circuits. Methods are presented to evaluate the adequacy of station grounds, including very large stations.

Instrument Measures Ground Impedance; C. A. Duke, L. E. Smith - Electrical World, Dec. 17, 1962, p. 50.

One page article in Today's Design Trends section describing an instrument for measuring ground impedance. The instrument was developed by the TVA and called LARGO (L and R ground ohm-meter).

Nomograph Determines Grounding-Rod Resistance; L. E. Whitehead - Electric Light and Power, Dec. 1962, p. 54.

This one page article presents a nomograph for solving:

$$R = \frac{\rho}{2\pi L}\left[\left(\log_e \frac{4L}{a}\right) - 1\right]$$

R = resistance of grounding rod
ρ = resistivity of soil
L = length of grounding rod
a - radius of grounding rod

Which Permanent Electrical Connection Should You Use?; J. H. Whitley - Electronics, Vol. 34, Jan. 25, 1963, pp. 50-1.

There are 18 different methods to choose from and a whole host of ways in which these methods can be applied. This table guides the user to an optimum choice of jointing technique.

Here are many characteristics of different materials and joining techniques, brought together into one comprehensive table for quick comparison. Cross-checking guides the engineer to the best technique for a particular job.

Interference Problems Due To Structures in High R.F. Fields; J. Barnett, D. Burrows - White Electromagnetics, Inc., Bethesda, Maryland, Final Report, Feb. 1, 1963.

The increased use of high-powered transmitters has made the existence of high RF fields more commonplace. The presence of structures within such fields gives rise to the possibility of various types of interference problems. This program covered a study and investigation of the interference problems of associated structures located in high RF fields. For the purposes of this program the interference problems were classified into two categories: (a) interference problems due to structural reradiations and (b) interference problems due to structural shielding or attenuation characteristics.

The basic tasks completed in this program included (a) investigation and experimental analysis of the manifestation of dielectric breakdown (corona) under various gap spacing and excitation,(b) experimental analysis of bonding techniques for use in mitigating interference due to dielectric breakdown, (c) investigation of structural shielding materials, (d) study of shielded enclosure measurement techniques, (e) study of antenna and structural grounding systems, (f) study of soil conductivity measurement techniques and (g) investigation of harmonic generation due to structural element non-linearities.

The discussion of corona deals with both pre-breakdown corona and the mechanism of dielectric breakdown. No attempt was made to determine material damage resulting from the breakdown, but only that portion of the problem which has RFI implication or RAD HAZ. Certain bonding

techniques are recommended and suggestions are presented for areas requiring further study.

This report contains methods of evaluating shielding measurements and provides new methods and philosophy for those measurements.

The structures grounding section is presented in the form of guidance criteria with a discussion of applicable soil conductivity measurements.

It was determined that (a) radio noise generated by corona below the arc-over voltage would not appear generally to be an RFI problem, (b) if insulator materials are used, the choice of materials should be based on reducing potential radio noise generation, (c) surface roughness of structural materials will contribute to corona generation, (d) adequate structural bonding techniques minimize corona generation, (e) good structural shielding qualities can be obtained through the choice of existing materials and (f) harmonic generation and subsequent reradiation of energy due to current flow through the non-linear system within the structure can pose a serious RFI problem.

<u>Wiring of Data Systems for Minimum Noise</u>; J. V. White - IEEE Trans. on RFI, Mar. 1963, pp. 77-82.

Proper wiring minimizes noise sources due to the undesirable coupling of circuits in a data system. Construction of a system central ground for minimum ground-resistance coupling is described. To eliminate other common-resistance coupling, this type construction is specified for all system nodes. Proper location of the ground and node structure permits wiring all noise sensitive circuits with twisted cable, thus minimizing coupling through mutual inductance. Proper shielding, for protection from electrostatic interference, is simplified by this construction. A set of explicit wiring rules, which implement this method is given. Examples of the application of these rules are included.

<u>Solderless Joints</u> - <u>The Technique of Wire Wrapping</u>; P. Atkinson - British Communications and Electronics, Vol. 10, Apr. 1963, pp. 288-9.

In many equipments, but particularly those subject to vibration hazards in service, soldered and screwed connections are no longer acceptable. In this article the performance and manufacturing advantages of solderless wrapped connections are compared with those of more traditional methods.

Total Shields Solve System Problems; Electronic Design News (EDN), May, 1963, pp. 90-.

This product-news item describes a Belden Manufacturing Co. cable shield dubbed "Beldfoil" and typical application configurations. This material is basically a fabricated sheath of very thin aluminum bonded to very thin Mylar, with a "drain wire", running with the shield, contacting the aluminum throughout the cable length. The material, used as described, is claimed to be "a practical solution that satisfies these critical requirements" for suitably reducing pickup and transmitted noise while saving space and weight, preserving flexibility, and standing up under extreme environmental conditions.

Dynamic Resistance Test of Spot Welds; Lloyd B. Cherry - IEEE Trans. on Commun. and Electronics, May, 1963, pp. 121-3.

The quality of a spot weld is determined by applying a periodic pressure while a test current is flowing through it. Poor quality is indicated by a variation in the weld resistance which results in a periodic potential across the weld. This potential is amplified for ease of detection. When a sinusoidal alternating current is used the presence of harmonic potentials indicates a poor weld. Removal of the fundamental by a filter is desirable before amplification.

The Electrical Role of Structure in Large Electronic Systems; Thomas H. Herring - Paper presented at the 5th National Symposium on Radio Frequency Interference, Philadelphia, Pennsylvania, June 4-5, 1963.

This paper is a discussion of design methods for satisfying the premise "that all chassis of an interconnected system should be at a common potential, within known limits." It also undertakes to "develop ways to protect the system from such differences as may arise. The design scope covers structural, mechanical, civil, facility, electrical and electronic contributions to the system." It treats local groupings as well as widely separated terminals, and presents handling bundles of circuit pairs in a manner analogous to handling single-circuit pairs.

Proposed Specifications for Electro-Magnetic Shielding of Enclosures and Buildings; L. G. Jahubec, Jr., H. H. Ohta, J. F. Fischer, Jr. - Contract NBY-32220 for U.S. Naval Civil Engineering Laboratory, by Genistron, Inc., Los Angeles, California, July 31, 1963.

Definitive specifications and architectural plans for (permanent) shielded rooms and buildings. Phase I - State of the art and design

basis. Phase II - Testing, experimental clarification. Phase III - Formulation of plans and procedure specs.

The Realization of Compatible Structure Grounding Systems; H. W. Ervin, D. R. Lightner, Robert Powers - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 155-182, Oct. 1963.

This paper discusses the design and implementation of grounding systems which must be used in structures or complexes which house electronic equipment which are susceptible to or capable of generating electromagnetic energy. Grounding systems are analyzed as two separate entities: (1) earth grounding system, and (2) reference plane grounding system. Criteria is developed for the design and implementation of compatible grounding systems based upon theoretical and practical considerations.

Electromagnetic Coupling Between Coaxial, Single-Wire, Two-Wire, and Shielded Twisted Pair Cables; M. Kaplit - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 183-192, Oct. 1963.

This paper presents the results of an experimental investigation of electromagnetic coupling between coaxial, single-wire, two-wire, and shielded twisted pair cables over the frequency range of 100 cps to 50 kc. The coupling was measured for matched, short-circuit, and open-circuit loaded cables when different combinations of similarly loaded parallel cables are used, enabling electric and magnetic coupling to be determined. These results are given as transfer impedances for different cable spacings and frequencies, worst case conditions being measured for shielded twisted pair cables.

A brief summary of shielding effectiveness measurements is given. These are contrasted with the technique presented in this paper since many of them determine the shielding effectiveness of only a single cable.

Achieving Electromagnetic Compatibility By Control of the Wiring Installatio
G. J. King - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 193-204, Oct. 1963.

Control of the wire routing and grouping of the many equipments and systems that are installed in modern aircraft is necessary to assure the electromagnetic compatibility of the ultimate system. Controlled classification of the wiring and the bundles reduces the interaction of equipments caused by the inadvertent coupling resulting from random installation. Wire routing control is mandatory to prevent the

interaction of individual systems and may also be required with wiring associated with systems that are susceptible to self-interference. The minimum design concept for adequate wiring isolation is defined in this paper. Definitive grounding of systems and the attendant grounding methods, including the bonding of all equipment installations, is a significant part of the overall compatibility of the electrical/electronic environment. Emphasis is directed towards this area.

<u>Shielding a Flight Vehicle Against Electromagnetic Interference During Te</u>
R. O. Lange - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 637-655, Oct. 1963.

This paper discusses the construction of a 40' x 40' x 20' high shielded anechoic facility, its evaluation, the method of physically supporting the vehicle during test, and use of the test chamber in a program of electromagnetic interference elimination on the Centaur space vehicle. The frequency range of interest is 200 MC through 6Gc. The discussion of construction covers principally the design of the facility and the solution of problems involved in maintaining the integrity of the metal shielding subsequent to providing the required apertures. Evaluation includes the results of tests made during various stages of construction and upon completion of alterations. Use of the chamber includes the purposes for which the facility was built and its present and anticipated usefulness.

<u>Shielding Theory and Practice</u>; R. B. Schulz, V. C. Plantz, D. R. Brush - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 597-636, Oct. 1963.

Plane-wave shielding theory is developed and discussed for a number of important cases such as single, double, and laminated shields. For application to design, the basic expressions are modified and plotted with universal parameters for convenient use in performance calculations of both solid and perforated sheets. Performance of solid copper and iron shields have been calculated and are presented in both tabular and graphical form. For these and other materials, measurement results of various experimenters are tabulated for a number of different material forms and for various incident-wave impedances. Some consideration is given to shielding discontinuities and trends in modern shielding enclosures.

<u>Low-Pass Transmission Lines for RFI Protection</u>; H. G. Tobin, L. J. Greenstein - Proc. 9th Tri-Service Conf. on EM Compatibility, pp. 134-154, Oct. 1963.

This paper deals with the analysis, design and fabrication of transmission lines which may be used to protect electroexplosive devices from inadvertant firing. Analysis was performed in order to determine the attenuation characteristics of various transmission lines. Initial investigation was concerned with the dissipation of a conventional line. Such a line is defined as one which has no variation in geometry as a function of length, in material properties as a function of frequency, and which has a homogeneous material between its two conductors. A general technique is described for optimizing the attenuation characteristics of a distributed line in order to achieve the desired amount of rf protection. This technique is applied to the conventional line and the optimum line parameters derived. It is shown that the attenuation of such a line will vary at a rate no greater than the square root of frequency. A more rapid change in attenuation is possible if a line utilizing two layers of dielectric is used. Analysis is given which shows, under optimum conditions, that the attenuation may vary as the second power of the frequency. The general optimization technique is used to derive the required line parameters for such a line. Difficulties in obtaining materials with the proper electrical characteristics, and the fabrication of lines using these materials are discussed. The results of measurements performed upon fabricated lines is presented. The correlation between the analytical results and those obtainable with a practical line is discussed.

<u>500 KV Dischargers</u>; V. P. Savel'yev, A. I. Bronfman - Edited Translation by Foreign Technology Division, Wright-Patterson AFB, July, 1971, FTD-MT-24-88-71. AD 730 367.

The article deals with 500 KV discharges, but especially magnetic-gate discharges. It brings to light some information about the development and research of new spark gap designs, in which the arc of an accompanying current is extinguished (suppressed) with the help of a magnetic field. The article also covers such topics as: permissible voltage in a discharger from the overheating conditions of shunting resistors; the greatest permissible voltage suppression voltage in a discharger during atmospheric surges and switching surges; the pulse breakdown voltage of a discharger; remaining voltage; the transmission ability of resistor plates and spark gaps.

<u>Design Your Grounding System</u>; Harvey W. Clifton - IEE Trans. on Aerospace, Vol. 2, No. 2, pp. 589-596, April 1964.

The objective of the information presented is to spotlight those problem areas concerning the philosophy of electrical grounds or grounding. Material presented is based on: 1) missile testing and launch problems

at the Atlantic Missile Range, and 2) personal studies, experiences, and observations of the author.

The lack of a good grounding philosophy is evident from the material presented. The need for more attention to grounding needs during Basic System Design is emphasized.

Some of the problems and factors involved are listed in the conclusions. Also, some recommendations for corrective improvement are offered.

A Theoretical Analysis of Grounding; Dr. J. H. Vogelman - IEEE Trans. on Aerospace, Vol. 2, No. 2, April 1964, pp. 567-588.

This study considers three cases, ideal, single point, and ground bus grounding networks. Theoretical analysis is developed by reduction to a composite network suitable in each case. Single point and ground but grounding networks are evaluated in terms of ideal ground plane. Derivations of these possible networks are provided, with evaluations of these networks with respect to ideal.

Derivation of a realizable equipotential plane when fed by two conductors spaced a finite distance apart is developed. Various simplification reducible to closed form are used to analyze the relative merits of a common ground bus versus a steel floor ground plane.

Evaluation of the derived relations and their application to the real case including recommendations for improving current grounding practice is provided.

George C. Marshall Space Flight Center National Aeronautics and Space Administration Specification Electromagnetic Compatibility; - MSFC-SPEC-279, June 1, 1964.

This specification provides system electromagnetic compatibility test requirements, subsystem interference test requirements, and subsystem susceptibility test requirements. System test requirements are applicable to entire space vehicles and all associated support equipment connected to the vehicle. Subsystem test requirements are applicable to individual electronic and electrical equipment to be installed in or associated with either the space vehicle or checkout facility. The test requirements specified herein shall be applicable for the following types of tests:

(a) System electromagnetic compatibility tests: Radiated and conducted interference and susceptibility tests performed to determine the ability of all individual vehicle subsystems to operate simultaneously without

performance degradation. (b) Subsystem interference tests: Radiated, conducted, tests performed to measure the magnitude of interfering undesired signals emanating from individual vehicle or facility equipments. (c) Subsystem susceptibility tests: Radiated, conducted, intermodulation, transient, cross-modulation and receiver input rejection tests performed to determine whether individual vehicle or facility equipments will satisfactorily operate when subjected to undesired external signals

Metal-to-Metal Bonding for Transfer of Radio Frequency Energy; Ross W. Evans - Internal Note, Instrumentation and Communication Division, Astrionics Lab, MSFC, June 25, 1964.

The measurement of bond impedance, from dc to 50 MHz, by determining insertion loss. Technique was adopted from U.S. Naval Air Development Center Report No. ADC EL - 172-50, July 20, 1950. Problem was to determine conformance of equipment bonds in a Saturn vehicle to MIL-B-5087A, bonding; Electrical, for Aircraft.

Radio Frequency Bonding ; Robert R. Robinson, Robert F. Wood, Ronnie H. Thompson - The Franklin Institute, Contract AF 33(615) - 1975, Task No. 43703, Air Force Avionics Lab, WPAFB, June 16 to Sept. 14, 1964.

Very brief summary of literature on investigation of bonding techniques.

Graphical Presentation of Electromagnetic Shielding Theory; W. S. Adams - Proc. 10th Tri-Service Conf. on EM Compatibility, pp. 421-449, Nov. 1964.

A digital computer was utilized to evaluate the general transmission line form of the shielding effectiveness equations for both high and low impedance sources. Results, not limited to either near or far field conditions, are presented in simple normalized graphs. Properties of common shielding materials are discussed and significant data expressed in a compatible graph.

This establishes a graphical technique enabling rapid, comprehensive analysis or synthesis of numerous practical shielding configurations involving solid metallic sheets. The significance of specific design parameters is vividly portrayed. Though applicable from one cps to infrared, this presentation is particularly useful for problems involving low-impedance (magnetic) radiation. It also provides a sound framework for expressing laboratory data in a more meaningful, applicable form.

Material properties (including variations with field intensity and frequency) and application limitations are summarily discussed. Selected configurations are analyzed to illustrate application to typical problems encountered in practice.

Study of Low-Frequency Fields for Coaxial and Twisted-Pair Cables; J. E. Bridges - Proc. 10th Tri-Service Conf. on EM Compatibility, pp. 475-495, Nov. 1964.

The low-frequency shielding properties of coaxial and twisted-pair cables is important to understand the various undesired cable-coupling modes. Emphasis has been placed on an empirical and theoretical study of the external magnetic fields arising from cables and cabling systems in the frequency range where the skin depth is considerably greater than the wall thickness of the outer conductor.

A 300-ohm TV twin-lead cable, a 7/8 inch diameter solid-copper coaxial cable, an RG 58U flexible coaxial cable, an RG 594 flexible coaxial cable and a No. 29 gauge twisted-pair cable were tested. Radial and axial leakage fields for a given configuration were obtained near the terminations. along the cable, and at some distance from the cable. Typical plots of these fields are presented. Theoretical analysis and laboratory measurements disclosed that the external low-frequency magnetic fields can arise from coaxial cables if the outer and inner conductors are slightly off center or that if unsymmetrical current distributions occur on the inner and other conductors for any reason. The external-field behavior and susceptibility of a coaxial cable may be characterized by an equivalent open-wire pair. Twisted-pair cables exhibited far less susceptibility or leakage fields than all coaxial cables tested at distances substantially larger than the spacing between twists. In order to predict the susceptibility and mutual coupling of coaxial or twisted-pair cables, consideration should be given to controlling mutual coupling paramters during the manufacture, test and installation which are not currently specified.

A Special Research Paper on Electrical Properties of a Flat Thin Conductive Strap for Electrical Bonding; R. J. Troup, W. C. Grubbs - Proc. 10th Tri-Service Conf. on EM Compatibility, pp. 450-474, Nov. 1964.

Obtaining low impedance electrical bonds at radio frequencies is important in the application of electromagnetic interference (EMI) control techniques. The determination of these bonding impedances, however; are difficult to predetermine without lengthy mathematical computations, because of the intervening bonding conductor.

This paper contains the results of mathematical and test investigations performed on a flat beryllium copper bond strap, with a length to width ratio of five to one, to determine its electrical impedance characteristics.

This paper also discusses the problem of obtaining electrical bonds and presents a popular solution for the calculation of conductor impedances, along with normalized nomographs for quickly determining the impedance, as a function of frequency and various length to width ratios.

Radio Frequency Bonding; William G. Reisener, Jr., Donald P. Klinns, Robert F. Wood - The Franklin Institute Contract AF 33 (665) 1975, Task No. 43703, AF Avionics Lab, WPAFB, Ohio, Sept. 15 to Dec. 14, 1964.

Experimental measurements were made of the impedance of a "strap." A slot was cut lengthwise of a cylinder, but a narrow bridge of the original material was left, to simulate a strap. The cylinder was placed inside a coil, and current was induced in the strap. A direct measurement of current (with a HP 1110A single turn probe) and voltage (with two HP 411A's, balanced voltage method) yielded 32.4×10^{-3} at 10 MHz. Computed value was 38.8×10^{-3} ohms.

Fundamental Problems of High Voltages in the Fields of Power Engineering, Electrical Engineering, and Electrophysics; M. V. Kostenko - Edited Translation by Foreign Technology Division, (FTD-HC-23-730-71), AD 731 909.

A detailed survey was made of those scientific and engineering problems in the field of high-voltage technology which the author feels should be studied and possibly solved with the 1966-1970 period. It covers the entire field from electrophysical processes in solid, liquid, and gaseous dielectrics, through EM effects and the high voltage problems in the field of physical equipment, to the problem of high voltage in power and electrical engineering.

Theoretical Analysis Measurements and Practical Applications of Flexible Ra Bonding Configurations; R. M. Soldanels - Aircraft Engineering Division, McDonnell Aircraft Corporation, St. Louis, Missouri, April 30, 1965.

Q meter measurements were conducted of impedances of bond straps, at up to 50 MHz. Straps included solid flat straps, braided types, and cable types.

Lightning Prediction and Protection Techniques; E. B. Arrowsmith - Aerospace Corporation, El Segundo, California, Oct. 1965.

The lightning protection at present launch support facilities was surveyed. An evaluation is presented and intended to help determine possible methods of reducing not only damage from lightning strikes, but also the resulting delays in launch schedules. As a basis for the evaluation, information is provided on lightning phenomena, lightning protection devices and systems, instrumentation for detecting and predicting thunderstorm activity and for measuring and evaluating lightning discharges, as well as an example of a lightning incident at a launch pad. Recommendations are made for improved protection.

Radio Frequency Bonding; William A. Reisener, Jr., Donald P. Kiwus, Robert F. Wood - Franklin Institute, Contract AF 33 (615) 1975, Task No. 43703, AF Avionics Lab, WPAFB, Ohio, Nov. 1965.

Methods of measuring bond impedance. Finding: impedance of strap bonds did not predict bond effectiveness. Technique developed is useful for butted plate bonds.

How and Where to Provide for Lightning Protection; Edward Beck - Maintenance Magazine, Oct. 1966, p. 28-31.

This short article presents an overview of representative lightning protection measures suitable for application in and around structures housing straightforward equipment such as motors and transformers.

How to Reduce Common-Mode Effects; W. McCullough - EEE-Circuit Design Engrg., Vol. 15, Feb. 1967, pp. 48, 50, 52-3.

This article is probably of little use to A 1401. It briefly discusses a few of the sources of common-mode voltages, encountered when accurate DC voltage measurements are being made. Also some methods of eliminating these common-mode voltages in DC voltage measurements are discussed. These methods are primary and secondary shielding of power transformer in the instrument and guard shielding.

RF Bonding Impedance Study; H. W. Denny, W. B. Warren - Technical Report No. RADC-TR-67-1061, Contract AF30 (602) - 3282 for Rome Air Development Center by Georgia Tech Engineering Experiment Station, Atlanta, Georgia, Mar. 1967.

Reactance of the bonding structure is the major impedance factor at high frequencies. Stray capacitance across the inductive of the bond forms a resonant circuit. Techniques are described for reducing impedance of bonds. Methods for display of bond impedance versus frequency are developed.

Radome Protection From the Higher Lightning Discharge Currents; J. D. Robb - LTRI Report #454, May, 1967.

The report shows before and after pictures of five different bonding jumpers that have been subjected to a lightning high-current component (simulated). The attached memo notes that an MS25083 Type 2 jumper was destroyed by a 75,000 amper test strip (survival level has been shown to be approximately 60,000 amperes) and discusses incompatibilities between MIL-B-5087B and the MS25083 bonding jumpers required thereby.

Simplified Shielding; Robert B. Cowdell - Geristron Division, Genisco Technology Corporation, July, 1967.

The problem first confronting shielded enclosure designers is that of determining the correct type of metal to be used and its required thickness. The shielding efficiency equations that must be solved to answer this problem are at best complex and cumbersome to handle. Graphical techniques developed to date are inaccurate, time consuming, and, in general, very difficult to use. The shielding charts developed for this presentation offer a simple, rapid method for solving the shielding problem in minutes. The examples herein demonstrate the great power and scope of the charts.

Electrical Grounding to Titanium Structure of Supersonic Aircraft; David F. Elliot - Supplement to IEEE Trans. on Aerospace and Electronic Systems, Vol. AES-3, No. 6, pp. 613-618, Nov. 1967.

Temperature rise and voltage drop were measured on titanium alloy sheet at the supersonic transport cruise conditions of 80,000 foot altitude and 450°F skin temperature. A grounding stud hardware configuration was determined, and the contact resistance between 6-4 and 8-1-1 titanium alloys and a nickel lug were analyzed.

The electrical resistance of a supersonic transport titanium cabin section was measured, and the consequence of electrical ground faults, arcs, lightning strikes to the titanium structure and other safety considerations associated with the electrical use of titanium is discussed.

Lightning Protection Problems for SST Aircraft; M. M. Newman, J. D. Robb, J. R. Stahmann - Supplement to IEEE Trans. on Aerospace and Electronic Systems, Vol. AES-3, No. 6, Nov. 1967, p. 607.

A variety of techniques have been developed for lightning protection of piston and turbine powered aircraft. Where lightning damage is not a safety of flight matter, the cost of protection must be balanced against the cost of repair, and in many cases, it is considered more economic to accept the lightning damage. For the new SST aircraft presently under development, special consideration must be given to any possible new hazards introduced by new construction materials or techniques and a brief review is presented of the present status of lightning protection for aircraft as an indication of the possible problems with the future SST's.

Low Resistance Electric Bonds; T. R. Wilson, J. R. Turner, E. M. Skene - Supplementary IEEE Trans. Aerospace and Electronic System, pp. 599-606, Vol. AES-3, Nov. 6, Nov. 1967.

Ways to achieve good bonds.

Electric Bonding Requirements for Avoidance of Fuel-Air Explosions; T. R. Wilson - Supplement to IEEE Trans., Aerospace and Electronic Systems, pp. 590-598, Vol. AES-3, No. 6, Nov., 1967.

Even when equipment housing is explosion proof, heavy ground current may cause high temperature in bad ground bonding. Only 0.37 volt drop ignited fuel-air mixtures, in an experimental study. Available fault current, and the resistance value of the hands in the ground circuit are parameters of concern.

Multiple Lightning Strokes Change Relay Schemes; J. W. Beville - Electrical World, Dec. 4, 1967, pp. 29-31, 73.

This article begins with a quick summary of the Lightning and Transients Research Institute's (LTRI's) triggered-lightning experiments, then uses the data in a development of a lightning-strike, and fault-currents, resetting protective scheme for power "feeder" lines.

Voltage Surges Induced on Overhead Lines by Lightning Strokes; P. Chowdhuri, Eric T. B Gross - Proc. IEE, Vol. 114, No. 12, Dec. 1961, pp. 1899-1907.

The paper analyses the voltage induced on an overhead line by the electromagnetic effects of the return stroke of lightning. The effects of a rectangular return-stroke current as well as currents having linearly rising front are analysed, assuming uniform charge density along the stroke channel and return-stroke velocity as a constant parameter. The analysis, which corroborates recent field data, shows that the induced voltage is not entirely a travelling-wave phenomenon. Contrary to the previous studies, this study shows that the waveshape of the induced voltage can be bipolar. Furthermore, the magnitude as well as the front time of the return-stroke current may be predicted approximately from the oscillogram of an induced voltage. The magnitudes of voltages induced by indirect strokes can exceed the basic impulse insulation level of high-voltage systems.

Die Cast and Mechanical Thermal Pulse Termination Techniques; R. H. Cushman - 16th Annual Wire & Cable Symposium, Atlantic City, New Jersey, Nov. 29 - Dec. 1, 1967, 28 pages.

This paper describes a continuing study program that has resulted in two new facilities of termination techniques. Shielded cables are terminated by a die casting process, allowing the simultaneous forming of functional piece parts. Bare wire, magnet wire, ribbon cable and insulated wires are terminated by the MTP family of techniques. Bonds can be made rapidly using semi-automatic, manual or portable tools. It is possible in many cases to make terminations through the insulation without stripping and appreciable contaminations.

Investigation of RF Bonding and Shielding Impedance Measurement Technique for Equipment; William C. Reisener, Jr., Robert F. Wood - Franklin Institute Research Laboratories, AFAL, WPAFB, Ohio, Nov. 1967.

Theories of (1) riveted plate over butt joint, viewed as a waveguide below cutoff, filled with adhesive or non-corrosive material, (2) high frequency induction coil probe, (3) time domain reflections from a bond in one wall of a parallel plate transmission line, (4) cavity Q changes caused by inserting bond in one wall of the cavity, (5) VSWR changes in a transmission line caused by terminating with a bonded joint.

Flexible Radio Frequency Bonding Configurations: Theoretical Analysis, Measurements, and Practical Applications; Roy M. Seldanels - IEEE Trans. EMC Vol. EMC-9, No. 3, Dec., 1967.

See Theoretical Analysis, Measurements, and Practical Applications of Flexible Radio Frequency (RF) Bonding Configurations since above article is condensation of previous article.

Electromagnetic Compatibility Guide for Design Engineers; Victor M. Turesin - IEEE Trans. on Electromagnetic Compatibility, Vol. EMC-9, No. 3, Dec. 1967, pp. 139-45.

The demands for more accurate instrumentation and checkout systems have led to new electromagnetic compatibility (EMC) requirements, which are accomplished by careful design considerations. An early approach to electromagnetic interference (EMI) control usually can result in a saving of long, expensive hours of redesign as well as program schedule delays. The reduction of EMI does not lend itself to hard and fast rules applicable to all situations. The intention of this paper is to provide suggestions which, if followed, will minimize the EMC problems.

Pulsed Induction Method; V. F. Bakhmutskiy - Telecommunications, Vol. 22, No. 6, 1968, pp. 49-55.

The pulsed induction method is shown to be feasible and convenient for locating cable punctures from above ground.

The relevant theory amounts to: (a) analyzing the pulse transients and finding the current in a punctured cable; (b) analyzing the magnetic fields due to current in the cable; (c) considering the screening and finding the transients in the screens; and (d) finding the induced EMF in the pick-up and optimal methods for dealing with it in the receiver-amplifier. Recommendations on the equipment design are included.

Nickel Plating for Improved Electrical Contact to Aluminum; N.T. Bond, F. L. McGeary - IEEE - Ind. & Gen. App. Conf. Rec., 1968, pp. 375-87.

A plating for electrical contact surfaces should be selected on the basis of acceptable electrical characteristics in conjunction with common contact surfaces and of adequate corrosion resistance in the anticipated environments. One of the problem electrical interfaces which must be considered is between the selected plating and nonplated aluminum contact surfaces.

Nickel plated contact surfaces provide both electrical dependability and corrosion resistance. This paper shows that nickel-plated conductors in electrical interfaces with plane, nonplated aluminum contact surfaces establish low contact resistance and maintain good interfacial fixity in service simulations that include corrosive exposure. The effect of nickel and tin plating thicknesses on interface performance is reported.

Electrical test assemblies included bolted spade, bolted bus overlap, and bus stack connections. Watts nickel was more satisfactory than semi-bright, bright, or electroless nickel platings. Silver, cadmium, copper, and tin platings were not satisfactory. Reference is made to other platings which indicate promise.

<u>A Test Instrument with a Direct-Reading Fault Bridge - Ohmmeter No. 18A</u>; G. W. Crosby - Post Office - Elect. Engrg., Vol. 60, 1968, pp. 285-7.

A test instrument is described which includes a new bridge network, enabling the conductor resistance to an earth or contact fault to be measured directly without the use of the conventional Varley or Murray formulae. The test instrument can also be used to measure loop resistance and insulation resistance; it will also locate disconnection faults.

<u>Protection Against Ground Fault Hazards in Industry, Hospital and Home</u>; W. H. Edmunds, J. H. Schweizer, R. C. Graves - IEEE Ind. & Gen. Appl. Conf. Rec., 1968, pp. 863-74.

Ground Fault Protection has been a subject for discussion for at least a quarter of a century. An article was published in Electrical Light & Power, November, 1945 with the title "The How and Why of Ground Fault Protection."

The more recent advances of the last decade in the art of solid state circuitry has made possible devices of superior performance and at much lower costs. Several companies now manufacture these.

In a recent advertisement, one of our larger electrical manufacturers comments, "Something is being done to correct the problem, Ground Fault Protection is <u>now</u> required by the National Electric Code, Article 110-10," (in effect since 1965).

Variation in sensitivity permits "Total Protection" that will protect property and protect life.

This paper discusses "Total Protection" for industry - including commercial buildings, hospitals, homes.

EMI Shielding With Electrically Conductive Pressure Sensitive Tapes; Charles L. Madden - 8th Elec. Insul. Conf., 1968, pp. 25-7.

The increase in importance of effective EMI (electromagnetic interference) shielding is obvious from the ever increasing space devoted to this problem in technical journals. The required attention to the shielding aspects of design of components and equipments, has become a significant part of manufacturing costs. This paper describes a new tool or tools to assist the design engineer in overcoming the problem of RF leakage. Pressure sensitive tapes with metal for backing have been available for some years and these do provide a limited degree of shielding. More recently metal foil tapes that are electrically conductive through, rather than just along the tape, have become available. These increase the utility of the metal foil backing in shielding applications by a factor of 100 +, because they now provide a mechanism for direct conductivity from a metal surface to the tape backing.

It might be well at this time to define how the term "conductive adhesive" is used, as it can be interpreted in several ways. In general "conductive adhesive" as used in this paper means a non-conductive matrix with distributed areas of high conductivity. Conductivity is changed by optimizing the ratios of the areas available for contacting the base metal. The term "conductive adhesive" is also used to describe an adhesive system that has "bulk conductivity". However, this type of adhesive tape is not currently being marketed.

Lightning Protection of Line Repeaters; E. Popp - IEEE Int. Conf. on Comm., Vol. 4, 1968, pp. 169-74.

Line amplifier transistors must be protected against even small overvoltages in the cables induced by lightning discharges parallel to ground by means of voltage limitation circuits consisting of gasfilled arrestors and semiconductor diodes.

Determination of the Influence of Power Lines on the Inner Conductors of Metal-Sheathed Cables; L. D. Razumov - Telecommunications, Vol. 22, No. 4, 1968, pp. 28-34.

The influence of power lines on metal-sheathed communications cables is discussed. The voltages and currents produced by proximity in the "inner-sheath" and "inner-ground" circuits are found. The true screening effect of the metal sheath is shown to depend on the (voltage, current) magnitude and on the (inner-sheath, inner-ground) circuit.

Conventional Arresters May Not Protect URD; Elect. World, Vol. 120, 1968, pp. 29 and 70.

This brief article presents a table comparing the discharge characteristics of low sparkover lightning arresters with those of conventional arresters. The author suggests that low sparkover arresters should be used on URD.

Detection of Fault Locations on Power Cables; H. Shinozaki, T. Kousumi - Electrical Engineering in Japan, Vol. 88, No. 1, 1968, pp. 27-33.

With the extensive use of power cable lines in cities of Japan, considerable attention has been given to the detection of fault locations. Until now, the fault location has been detected according to the following three steps: 1) burning away the faulty part of the cable; 2) detecting the approximate location of the fault by sending the pulse or by the bridge method; and 3) determining the fault location more accurately by the acoustic method or by the search coil method.

This paper proposes a new method which solves the above-mentioned difficulties. This method is originated from the so-called BW method to test a communication cable. The advantage is that the above-mentioned three steps can be carried out simultaneously. In addition, the work in the first and second steps can be finished in a very short time. When the first and second steps are carried out simultaneously, the discharge time lag at an incompletely grounded fault creates another problem. This difficulty can be solved by applying a high-voltage pulse to the faulted line and measuring it at the unfaulted line.

The Shielding Effect of a Pipe Cable; T. Yamaguchi - Electrical Engineering in Japan, Vol. 88, No. 5, 1968, pp. 25-34.

This paper analyzes theoretically the shielding coefficient and the zero-phase-sequence impedance of pipe-type cables. The validity of calculation formula is confirmed by comparison with the measured results.

Interference Experienced in a Communication Line Due to a 11.4KV, Three-Phase, Four-Wire Multiground System; K. C. Yeh - Electrical Engrg. in Japan, Vol. 88, No. 2, 1968, pp. 7-17.

This paper reports the measured results of the interference voltage of the telephone line in Taiwan and proposes a three-phase, four-conductor, unimultiground system as a countermeasure to reduce this noise.

Corrosion Aspects of HV DC on Buried Telephone Plant; L. E. Fiorito - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-87, No. 1, Jan. 1968, pp. 35-40.

High-voltage direct-current (HV dc) transmission is proposed by the Bonneville Power Administration (BPA) to transmit power from Oregon to southern California, via a balanced line. Balanced transmission lines pose little or no corrosion problems to buried lead telephone cables. However, because of the use of ground return under fault conditions or scheduled line repairs, the corrosion aspects of continuous ground return operation have been considered.

A theoretical analysis of the corrosion problem has been made to establish the relationship between the apparent earth resistivity, the leakage current on buried cables, and the current at the electrode. Formulas are presented which permit determination of the required minimum separation, between buried noninsulated cables and a current electrode. Field measurements made at The Dalles, Oregon and applied to the equations indicate that with a current electrode operating at 2000 amperes, a minimum separation of 3.8 miles is required between it and adjacent noninsulated cables.

The leakage current at a break in the coating of insulated cables is also considered, but the unknown quantity of leakage resistance of the jacket prevents the development of useful general approximations. Cathodic protection, applied to insulated cables in an area where the earth potential around a current electrode is significant, can be used to obtain protection.

These same techniques may be applied to determine the corrosion hazard at other locations.

Tests of Aluminum Bonding Jumpers; J. D. Robb - LTRI Report Lightning Protection Development for Aerospace Vehicles, Jan., 1968.

We have completed tests on aluminum bonding jumpers to determine if there is any valid reason they should be withdrawn from stock. We are enclosing an excerpt from an interim report covering the tests. As may be seen from the report, we have found that although the bonding resistance does vary with flexure, there seems to be no problem with their carrying the required lightning currents. We plan to continue the program with tests of bonds weathered in service and also bonds fabricated locally at a military base and will issue a report on these as a supplement.

RF Shielding Design; Richard B. Schulz, George C. Huang, Walter L. Williams - IEEE Trans. on Electromagnetic Compatibility, Vol. EMC-10, No. 1, Mar. 1968, pp. 168-75.

An RF shielding design procedure based on a nonuniform transmission-line analogy of shielding is presented. The theory treats the propagation of an EM wave through the walls of a shielding enclosure as a path through the material itself in parallel with one or more paths through defects, seams, or other discontinuities in the shielding structure.

Data necessary for the design of a shield are presented in the form of material factors, seam factors, size factors, and other. Factor dependency on frequency is discussed. Two typical design examples are given.

Protecting Data From the Ground Up; R. I. Demro - Electronics, Vol. 41, No. 9, Apr. 29, 1968, pp. 58-64.

This article presents methods of eliminating error voltages that are created by circulating currents between pieces of separately grounded electronic equipment by using differential data amplifiers.

Investigation of Lightning Damages on Distribution Lines; Ken Uehara, Genichi Ohwa - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-87, No. 4, April, 1968, pp. 1018-25.

Lightning damage on 3.3- and 6.6-kV overhead distribution lines is investigated. The damaged apparatus and its components are distributed on the line in the vicinity of lightning stroke point. Induced lightning surges are very dangerous at the line ends and they attack the poles branching the line harder than the neighboring poles. It is considered that blowing of primary fuses for distribution transformers is often caused by power short circuits formed by flashover of induced lightning surges on the bushings when lightning strikes close to the line. The appearance of lightning damage suggests that hitherto accepted mechanism of induced lightning surges should be re-examined. Also the actual results show that protective effect of overhead ground wire on induced lightning surges is considerably high.

Nomograph Helps Find Resistance of Grounding Electrodes; L. E. Whitehead - Elec. Light & Power, Vol. 46, No. 5, May 1968, pp. 120-1.

This paper presents and explains a nomograph for solving the following e.q.:

$$R = \frac{\rho}{4r} + \frac{\rho}{L}$$

Where:

ρ = lowest resistivity measured via the 4-probe test
r = radius of circle equal to grid area
L = length of grounding conductors
R = resistance of electrode

<u>A Transistorized Video Line System</u>; G. Comber - IEE Conf. Pub., Vol. 46, Pt. 1., Sept. 1968, pp. 6.4.1-6.4.4.

This paper describes objectives, assumptions, design criteria, and lightning protection for a transistorized, 25-mile-long color TV link.

<u>Line Mock Up Aids "Safe Grounding" Sessions</u>; J. C. Flippen - Electrical World, Vol. 170, No. 13, p. 31, Sept. 23, 1968.

A teaching aid for linemen is described, which demonstrates the lack of protection in bonding a deactivated line to towers on both sides of a work-position tower. An accidental fault to the "deactivated" line places full potential from line to tower at the work position.

<u>Quiet</u> - <u>Wiring Zone</u>; Robert E. Goers - IEEE Ind. & Gen. Appl. Group, 3rd Conf. Rec., Sept. 29-Oct. 3, 1968, pp. 249-53.

The development of solid state control and switching has been a boon to the electrical/electronic circuit designer but has proved to be a headache to those concerned with the interconnection of the "black box" and its associated equipment. Careful attention given to proper wire selection and to installation procedures will largely eliminate that noise which might otherwise cause equipment failure.

<u>Protection of Structures Against Lightning</u>; R. H. Golde - Proc. IEE, Vol. 115, No. 10, Oct. 1968, pp. 1523-9.

In contrast to earlier revisions of the original Code of Practice CPI 1943, the latest revision, published in 1965 introduces several important additions and modifications, based on new concepts of lightning protection and taking account of modern building methods and

materials. The paper discusses these modifications and the reasons for their introduction.

Impulse Characteristics of Driven Grounds; H. M. Towne - General Electric Review, Vol. 31, No. 11, Nov. 1968, pp. 605-9.

Studies of the impulse characteristics of several driven-pipe grounds have been made by the Research Lab of the Lightning Arrestor Engineering Department at Pittsfield, using the cathode ray oscillograph. The following areas were studied: Comparison of Impulse Resistance with 60 hz Resistance; Comparison of Single and Multiple Pipe Grounds; Change of Impulse Resistance with Salting of Ground; and Effect When in Series with Arrestor. This paper describes these tests and discusses the results.

Development of Extended Range Shielded Enclosures; Roger C. Follett, Lawrence Beard - Sprague Electric Company, North Adams, Massachusetts, Technical Paper TP 69-9, 1969.

This paper presents some of the results of a development program launched by the Sprague Electric Company five years ago. A primary objective of this program was to further the state of the art of low-frequency low-impedance (magnetic) shielded enclosure performance.

The paper describes the evaluation of shielding materials, compares several methods of measuring shielding effectiveness with theoretical performance, and discusses the development of ancillary devices.

Discontinuities in shields such as doors, ventilation apertures, and other miscellaneous penetrations have always been the weakest parts of shielded enclosures. This paper also treats the development of methods to improve the performance of such discontinuities to acceptable levels.

Presented in graphical form is shielding information on various shield membranes and ancillary equipment -- usable as design guides to achieve a wide variety of performance requirements.

Electrical Shock & Reliability Considerations in Clinical Instruments; J. G. Neuland - IEEE Symposium on Reliability, Vol. 2, 1969, pp. 308-13.

With the great upsurge in more advanced medical care, the number of electrical instruments and equipment in direct contact with patients has greatly increased. The presence of this large volume of electrical medical equipment places a major responsibility on the instrument and

equipment manufacturers to insure that their products do not present a shock hazard. This paper is concerned with identifying electrical hazards and the effect of reliability on the safety of the patient and user.

<u>"Death" From Lightning and the Possibility of Living Again</u>; Helen B. Taussig - American Scientist, Vol. 57, No. 3, Autumn, 1969, pp. 306-316.

This article relates some history of lightning strike incidents and their effects; discusses power wire shock and lightning shock comparitively and what to do about them (but no detail); and gives a number of precautions against being struck.

<u>New Method for Earth Potential Balancing of A.C. Bridges</u>; E. Toth - Periodica Polytechnica, El. Vol. 13, No. 4, pp. 287-302, 1969.

Classical methods of reducing bridge measurement errors, which are due to stray impedances are carefully reviewed. The Wagner method is seen to be restricted to low frequencies, and limited by mutual coupling. Both manually and automatically adjusted voltage insertion methods have had similar drawbacks. A new method, using a summing amplifier, is shown to reduce errors by a factor 1/(HA) where A is amplifier gain. Only three balancing iterations are required, even at the upper frequency limit.

<u>Electrical Hazards in Hospital Instrumentation</u>; J. A. Hopps - Proc. Annual Symposium on Reliability, Chicago, Illinois, Jan. 21-23, 1969, IEEE, New York, Vol. 2, No. 1, 1969, pp. 303-7.

Electronic equipment for hospital patient treatment or monitoring is often operated by staff with little or no technical knowledge. It may be combined with other instruments in procedures which introduce the critical hazard of internal electric shock. Although such instruments usually are quite safe when used alone, in combination with other equipment they may provide lethal fault currents through the patient's body.

Increased awareness by the design engineer and medical staff can reduce the alarming incidence of electric shock fatalities in our hospitals.

Low Current Tests Pinpoint Cable Defects, Cut Fault Damage; G. T. Lautenschlager - Electric Light & Power, Vol. 47, No. 1, Jan. 1969, pp. 74-5.

Constant current from a street lighting transformer quickly burns through defect in rubber insulated cables. Damage to other cables is minimal, repair is limited to faulted portion of defective cable only.

Telephone-Interference Calculation for Multiconductor Power Lines; W. Scott Meyer, Hermann W. Dommel - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-88, No. 1, Jan. 1969.

Previous work on power-line-produced telephone interference has dealt with the case of a single equivalent power conductor. This paper presents the theory applicable to a multiconductor power line excited by general, linear networks. A self-contained digital-computer program employing these techniques has been written. It rigorously handles the important case of actual communication line-power line crossings. A comparison of the computer results with experimental measurements is provided.

Lightning and Aircraft; A. W. Turner - Airlifters, Vol. 3, No. 1, Winter 1968-69, pp. 24-52.

The primary aim of this article is to explain, simply, the phenomenon of lightning and its effects on aircraft. Many think an aircraft can "attract" a lightning strike from a great distance and that such attraction could be reduced by more careful design. Also, many think an airplane, by static friction, can actually originate a damaging lightning bolt, labeling such an event "electrostatic discharge" to distinguish it from a "natural" strike. These pages may help dispel such misconceptions.

The main points are in Part One, which includes also a short history of research and a brief description of lightning. Part Two, in effect, enlarges upon the first part, particularly in such aspects as aircraft design, maintenance, and flight. Last, the Appendix endeavors to describe the various processes involved in the lightning flash in terms requiring minimal knowledge of things scientific.

Techniques for Splicing and Terminating Aluminum Power Cable; Richard A. Burkhardt, James W. Fitzhugh - IEEE Trans. on Industry and General Applications, Vol. IGA-5, No. 1, Jan/Feb. 1969, pp. 101-5

Because of the phenomenal growth of underground power distribution, the economics of using polyethylene or cross-linked polyethylene insulated aluminum conductors has gained wide acceptance. With polyethylene or cross-linked polyethylene insulated conductors, however, the techniques of splicing and terminating differ from conventional paper insulated cables to a degree which requires the reeducation of the cable splicer.

The techniques involved when splicing or terminating aluminum conductors require a thorough understanding of splice and termination construction principles. It also requires an understanding of the materials used and their application so a reasonable service life can be expected of splices and terminations.

The techniques derived to date have proved that a long service life can be realized if construction principles and material application are understood by field personnel.

<u>Accelerated Aging Tests of 69-kV Cross-Linked Polyethylene Cable and Joints</u>; James L. Williams, Jr., Aldo Zanona, Alfred R. Lee - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-88, No. 2, Feb. 1969, pp. 157-70.

Test evaluation of 69-kV cross-linked polyethylene (XLPE) cable and joints for use with such cable is described. Joints suitable for connectin together either lengths of 69-kV cross-linked polyethylene (XLPE) cable or XLPE cable to solid-type paper insulated 69-kV cable are studied. It is shown that the characteristics of the tape selected greatly influence the performance of the joint. The thermal resistivity and the thermal expansion of cross-linked polyethylene are also examined.

<u>A Plain Man's Guide to Lightning Protection</u>; R. H. Golde - Electronics & Power, Vol. 15, Mar. 1969, pp. 84-6.

Although no more than about ten people are killed annually in Britain by lightning, even this figure could be readily reduced by a wider understanding of basic lightning protection, and in countries where lightning is much more prevalent the problem of both structural and personal protection is of course, of great importance.

<u>Fundamentals of Corrosion and Corrosion Control for Residential Subsurface Transformers</u>; Gordon C. Nonken - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-88, No. 3, Mar. 1969.

The severe and varied environment of residential subsurface transformers (RST) requires different materials and means of corrosion protection from the pole-top transformer. The galvanic characteristics of mild steel and stainless steels are presented along with corrosion test data on mild steel and ferritic stainless steels in RST environments. Also, field test data on corrosion and cathodic protection of transformers in typical RST installations are given.

Cables and Accessories:

Some Trends in Standardization, Rationalization and Ratings; C. C. Barnes, E. Hill, C. T. W. Sutton - Proc. IEE, Vol. 116, No. 4, Apr. 1969, pp. 548-60.

Prior to nationalization of the electrical supply industry in 1948, with more than 500 separate undertakings, design of equipment frequently depended on the preferences of individual engineers. This situation was influenced by local conditions or precedents, and often by forceful commercial pressures. In 1949, after nationalization, joint consultative committees were formed, with the CEGB Area Boards and the electrical manufacturing industries, to discuss immediate requirements and to plan future activities as electricity demand steadily increased. The manufacture of electrical cables was included in this scheme, and this paper discusses the results achieved by this collaboration and surveys the possible fields for future discussions. A number of examples have been chosen to illustrate the continuous progress:

(a) standardization and rationalization of cable types and dimensions
(b) initiation of type-test procedures for proving new designs of cables and ac
(c) provision of a forum to agree procedures for assessing new techniques and s problems arising from service experience

Future activities are recommended, considering the advantages of collaboration and the greater facilities for research and development now available. It is suggested that the emphasis is no longer on the e.h.v. field, but on the production of designs in the intermediate-voltage range to improve the economics of underground distribution.

Right Equipment Mix Speeds Cable Fault Location; P. T. Howe - Electric Light & Power, Vol. 47, No. 4, Apr. 1969, pp. 75-7.

This article discusses how trained operators trace buried cable and cable faults on the CP system.

Dynamic Ground Detector Guards Hospital Power System; Robert J. Lawrie - Electrical Construction and Maintenance, Vol. 68, No. 4, Apr. 1969, pp. 106-9.

In an intensive coronary-care section, special electrical systems protect patients from possible shock. Because modern medical instrumentation requires bodily contact with probes, etc., patients are susceptible to shock hazard from low-level currents. Maximum protection is provided by a new dynamic-type hazard indicator installed on an isolated ungrounded distribution system.

How to Troubleshoot Medium-Voltage Power Cable; C. J. Oatess - IEEE Trans. on Industry and General Applications, Vol. IGA-5, No. 2, Mar/Apr. 1969, pp. 163-8.

Medium-voltage power cables are manufactured and inspected to rigid specifications based on designs of proven reliability. Trouble-free service can be expected provided the proper cable is chosen for the application and correct installation procedures have been followed.

Cable failures do occur since ideal conditions do not always exist through the cycle of cable choice, installation, and application. When a failure occurs, it is necessary to determine the cause.

Factors responsible for cable failures are categorized and preventive measures suggested.

Screening Factor of Pipe-Type Cable Systems; S. C. Chu - IEEE Trans. on Power Apparatus and Systems, Vol. PAS-88, No. 5, May 1969, pp. 522-8.

After reviewing the background of zero sequence impedance of pipe-type cables, the paper describes in general the longitudinal voltages induced in adjacent auxiliary cables due to a fault in power transmission systems. The magnitude of the induced voltage is influenced by the screening effect of the power cables. The screening factor and the impedance of the steel pipe have been measured in the laboratory by short-circuit tests on a 275-kV cable sample with a simulated ground path. The results are used to illustrate the application in induced voltage calculations in a typical example.

It is shown that, owing to the very low impedance of the steel pipe, it gives a very low screening factor, i.e., low longitudinal induced voltages in neighboring auxiliary cables. Hence an economical design of auxiliary cables may be used.

Corrosion of URD Cables: G.C. Nonken, T. Holtgrieve, D. LeBeau, A. M. Lockie, J. P. Lozes, W. D. Lawson, R. R. Lieberman, J. B. Vrable - Electrical World, Vol. 171, No. 18, May 5, 1969, pp. 88-106.

Corrosion results in more damage to materials than any other single cause. It is a very complex mechanism, imperfectly understood even by those most knowledgeable in the field. And yet, impelled by the insupportable pressures of legislation and public desire, utility engineers, often unfamiliar with even the rudiments of the 13 basic types of corrosion, are being forced to put distribution systems underground.

Unfamiliarity with corrosion phenomena has already brought some disastrous results. The greatest enemy is always ignorance, and ignorance of the conditions that cause corrosion will inevitably lead to corrosion.

This report attempts to dispel some of the air of the unknown that surrounds the subject, especially for those who have not had extensive underground design experience. It may disappoint those already sentient in this area, for it is essentially a primer and hopefully will serve to alert those not now conversant with the types of corrosion found in URD.

Corrosion is an implacable enemy, but not an invincible one. Systems can be designed to function well in the hostile underground environment, but only if we are aware of the nature of the enemy.

Lightning and the Transmission Engineer: A. B. Wood - Electronics and Power, Vol. 15, June 1969, pp. 195-200.

This is a general discussion article on lightning for the transmission engineer. It is based on the IEE North-Eastern Power Section chairman's address and contains little detail. It does, however, include the following possibly useful items.

(1) A clue to a "new" British code of practice which has an "Interesting" points system for determining whether lightning protection is necessary at
(2) A graphical method for determining approximate zones of lightning protection provided by overhead "earth wires."
(3) A set of angles for determining protection zones offered by "earth wires" of various heights up to 150 feet . (These might be extrapolated.)
(4) A world-wide (though not highly detailed) isoceraumic map (presumably good as of publication, June 1969).
(5) Discussion of an electronic lightning flash counter.
(6) A brief rationale that for system voltages above about 300 kV "it is rarely justifiable to increase insulation purely for lightning reasons."

Direct-Buried Splice Fights Corrosion, Yields Savings; N. E. Piccione - Electrical World, Vol. 171, No. 26, June 30, 1969, pp. 28-9.

This two page article describes a "new" product developed by Protexulate Division of Pluess-Staufer, Inc. which is being used by Long Island Lighting Co. on underground slices to prevent corrosion. The product is a splicing kit which contains a hydrophobic powder as an insulation for the splice. After the splice is made using the materials in the kit the joint is surrounded by 5 inch of the powder and corrosion is prevented.

Double Screened Transformers to Reduce Interference From Power Lines; C. Guld - Proc. 8th Int. Conf. on Med & Biol. Engrg. & 22nd Annual Conf. on Engrg. in Med. and Biol., Chicago, Illinois July 20-25, 1969, Session 14-11.

This very brief (1 page) article presents the advantages of two electrostatic screens over one screen in transformers. With a single screen transformers stray currents in the ground wiring is possible due to the capacitance between transformer coils, where double screens prevent this.

The 3EA1001 - A New Siemens Low-voltage Lightning Arrester; Werner Jakszt, Gustav Schmalz - Siemens Rev., Vol. 36, No. 7, July 1969, pp. 179-82.

Public utilities have been using low-voltage lightning arresters for more than 30 years to protect electrical installations against atmospheric overvoltages. Of the large number of Siemens valve-type lightning arresters installed during this period, the H 400 arrester has proved particularly successful in overhead line systems for 220 and 380 V.

Electrical Grounding: Safe or Hazardous?; R. H. Lee - Chemical Engrg., Vol. 76, No. 16, July 28, 1969, pp. 158, 160, 162-4, 166.

When should an electrical system not be grounded? What are the hazards of grounding? What methods and materials are best? These and other questions are answered for supervisors who want to know more about this difficult subject.

Electromagnetic Compatibility Requirements for Space Systems; C. B. Pearlston, Jr. - Aerospace Corp., El Segundo, California Contract AF 04 (695) -1001, FO4 701-68-C-0200, F04701-69-C-0066. Supersedes TOR-1001 (2307)-4, Revision 3, dated July 3, 1967.

Philosophy of case shielding; bonding (0.0025 ohm dc resistance from equipment to basic structure); instrument grounding; ground plane for system tests; probe antenna for system tests.

Protecting Open Circuit-Breakers Against Lightning; E. Ruoss, H. J. Vorwerk - Brown Boveri Rev., Vol. 56, No. 9, Sept. 1969, pp. 424-33.

This article examines the problem of lightning strokes hitting high voltage transmission lines in rapid succession. Also it is shown that lightning arresters on the line side provide the best protection for open breakers.

A lightning stroke can cause a single-phase earth fault and in certain isolated cases a two or even three-phase short circuit. The distance protection system instigates a single or three-phase interruption with rapid autoreclosure of the breakers at both ends of the line. If the fault is cleared normal operation is resumed, but if it persists a definitive interruption takes place.

Certain conditions can arise, however, which disrupt the normal sequence of autoreclosure and can place an open breaker in jeopardy, especially if an atmospheric overvoltage occurs during the interval. Similar conditions can also occur without autoreclosure if the breakers at the ends of the line are open and the isolators are still closed. These cases are discussed using several actual examples and the appropriate protection arrangements are given.

Shielding for Wire & Cable - Types & Applications; R. H. Meyer, Jr. - Insulation (Libertyville, Illinois), Vol. 15, No. 10, Sept. 1969, pp. 45-6.

This is a very brief general discussion type paper on the types of wire and cable shields and their applications.

Lightning Protection of Structures; P. F. Offerman - IEEE Conf. Record, 4th Annual Meeting, Industry and Applications Group, Oct. 12-16, 1969, pp. 365-370.

The zone protected by a grounded steel mast is usually considered to be a cone. This paper developes the geometry of lightning protection, based on the generally accepted concept of the mechanism of the lightning stroke. Equations are derived relating the zone protected by a mast to mast height and striking distance of the lightning stroke, and design curves are developed. Grounding resistance, lightning conductor size and bound charges are also considered.

Review of Bonding Practices of Ship-to-Shore Facilities Handling Petroleum Products; Adrian L. Verhiel - IEEE Trans. on Industry and General Applications, Vol. IGA-5, No. 5, Sept./Oct. 1969. pp. 624-32.

In the oepration of a ship-to-shore or ship-to-dock oil handling facilities, the spillage of petroleum products can and frequently will occur as a normal part of the operation. The vapours of the spilled product, under certain conditions, can form a hazardous atmosphere which, when ignited, will lead to explosions and fires. One of the potential sources of ignition has long been recognized as arcs resulting from uncontrolled currents or from sparks resulting from uncontrolled potentials. In order to avoid, minimize, or render harmless these currents and potentials, it has been the practice at the product handling facilities, to metallically interconnect and/or connect to earth the handling facilities. Terminology, stray current and potential phenomena, present bonding practices, and policies as carried out by a number of petroleum product handling companies or as required by regulatory bodies and Harbor Boards are reviewed.

Measurement of the Resistance of an Earth-Electrode System Covering a Large Area; M. Ouyang - IEE Proc., Vol. 116, No. 11, p. 1984, Nov. 1969.

A suggested graphical method for simplifying Tagg's method of 1969.

Gas Tube Arresters; E. L. Fisher, J. B. Eppes, Jr. - Proc. Nat. Electron Conf., U.S. Department of Agriculture, Vol. 25, Dec. 8-10, 1969, pp. 366-70.

This paper reports on the present state-of-the art of gas tube arresters as disclosed by laboratory tests on a number of makes and types of commercially available gas tubes.

Measurement of Ground Conductivity by Dipole Method; T. Sato, Y. Takano - Elec. Engrg. Jap., Vol. 89, No. 12, pp. 43-50, Dec. 1969.

AC power lines induce noise in telephone lines. Calculation of the induced noise requires accurate measurement of ground conductivity. Methods used have included a four-electrode method, a probe line method and a coil method, all of which require a large measurement space. A four-electrode method is developed, with spacing on the order of 100 meters. The measured and calculated induced voltages using the dipole method show good correlations up to 1000 Hz.

Low Frequency Electrical Interference in Process Control Computing; I. J. Dick - IEE, Conf. Publ. No. 65, Vol. 65, 1970, pp. 74-75.

This brief paper cites common sources of interference into process control computers describes the principal types of such interference, differentiates between electrostatis and electromagnetic effects, and enumerates some basic relationships involved with magnetic induction between power and signal cables.

A Lightning Protection Unit for Use with Industrial Process Control Equipment; S. A. Foster - IEE Conf. Publ. , No. 65, 1970, pp. 43-45.

This short article touches on the nature of lightning transients that must be protected against; the practical design of suitable protection, using primary and secondary protection; the transient performance of some devices; and the barest rudiments of installation and earthing.

The Reduction of Overvoltages and Contact Arcing in Power Circuits by the Use of Voltage Dependent Resistors; A. D. Miller - IEE Conf. Publ. No. 65, Vol. 65, 1970, pp. 46-49.

This short article begins with a discussion of switching voltage-transients sources/causes and associated problems created thereby. It next quickly describes the character of voltage-dependent resistors, then goes on to discuss switching of direct currents in the glow and arcing regions and of alternating currents in inductive, resistive, and capacitive circuits, in each case slanting the discussion to the use of voltage-dependent resistors.

This article appears to be only of incidental interest to Proj. A-1401, for while it is quite germane to the general subject of EMI/EMC, it scarcely fits the categories of grounding, bonding, shielding, and lightning protection.

Splicing and Terminating Cable Thru 45Kv; O. L. Willis - IEEE Annual Pulp and Paper Ind. Tech. Conf. Rec., Vol. 16, 1970, pp. 1-11.

Terminating and splicing of electrical power cables involves certain basic principals that are applicable through all voltage ranges. The intent of this paper is to review these principals and their implementation on modern power cables with currently available splicing and terminating materials. The newly available polymers have resulted in cables capable of operating over a very wide temperature range, but if these advances in cable technology are not matched by splicing and terminating skills and materials, the utility of these advances cannot be realized.

Field Testing of Electrical Grounding Rods; R. W. Drisko, A. E. Hanna - Naval Civil Engrg. Lab., Port Hueneme, California, Feb. 1970, NCEL-TR-660, 61 pages.

In cooperation with the National Association of Corrosion Engineers, NCEL conducted a 7 year program of field testing metal rods for electrical grounding. Single rods of galvanized steel, cu-clad steel, zinc., magnesium, and aluminum were tested along with couples of these to mild steel rods. Sets of both single and coupled rods were removed, cleaned, and weighed after 1, 3, and 7 (or 5) years. Potential, resistance, and current measurements were made monthly as far as practicable. Weight losses and electrical data were analyzed for correlations. It was concluded that type 302 stainless steel and type 304 stainless-clad steel rods were the best choices for general use.

Single Ground Serves Twin-Delta Power Transformers; T.V. Patel - Electric Light and Power, Vol. 40, No. 2, pp. 86-7, Feb. 1970.

One leg of transformer band A is connected to one leg of band B. All legs of band B are then connected to ground through a grounding transformer.

The Water Utilities Look at Electrical Grounding; Lee B. Hertzberg - IEEE Trans. on Industry and General Applications, Vol. IGA-6, No. 3, May/June 1970, pp. 278-81.

The objections of the water works industry to the use of water system piping for electrical grounding purposes, and the latest revision of the American Water Works Association policy on grounding are discussed. Electrical engineers engaged in design of grounding protection are

alerted to the need for development of new, independent, and reliable grounding techniques.

Infrared Use for Maintaining Power Cables; I. A. Nichols - IEEE, 16th Annual Pulp & Paper Industry Conf. Rec., Vancouver, B.C., June 17-19, 1970, 11 pages.

This article presents a method of determining joint failure using the fact that as a joint fails its temperature increases. This increase in temperature can be detected using radiometers or infrared pyrometers. The paper considers the questions of what they are and how they work; their advantages and disadvantages.

A Comparison of Concrete Encased Grounding Electrodes to Driven Ground Rods; Paul Wiener - IEEE Trans. on Industry and General Applications, Vol. IGA-6, NO. 3 pp 282-7, May/June 1970.

An experimental study was made to compare the efficacy of concrete encased grounding electrodes to that of driven ground rods for grounding residential and small commercial electric services. This study extended over 14 months and included a very wet winter and a dry summer. The ground resistances of both grounding systems were monitored for the first five months. Current from an isolated 120/240-volt system was then circulated through both grounding systems for the following six months. At the end of the 14-month period, fault current from power systems of 2.4 to 20 kV were applied to both grounding systems. The ground resistance variations were recorded in all cases.

The resistance of the concrete encased electrodes was generally lower than that of the driven ground rods and the concrete encased electrodes were more effective in carrying current from the 120/240-volt systems. There did not seem to be much difference in the current carrying ability of both systems under fault currents from the 2.4-to 20-kV systems. It was apparent that the concrete encased electrodes were in better physical condition at the end of the tests than the driven ground rods as the driven ground rods were showing the effects of corrosion.

Under sustained fault-current conditions, driven ground rod resistances increased from a value of 10 to a value of 40 . (Probably because of soil drying). The concrete encased electrode resistance remained constant. The concrete encased electrodes showed little evidence of corrosion; the driven grounds all showed corrosion.

Use of Concrete-Enclosed Reinforcing Rods as Grounding Electrodes; E. J. Fagan, R. H. Lee - IEEE Trans. Industry and General Applications, Vol. IGA-6, No. 4, pp. 337-48, July/Aug. 1970.

H. G. Ufer (see ref. 1 in this paper) had found out in 1964, that reinforcing steel in footings constitutes effective grounding electrodes. Weiner (ref. 4) had shown that such systems sustain considerable ground currents with less corrosion than driven rods. A welded connection by a short tie bar from one of four (or more) vertical rebars to an anchor bolt provides for good electrical connection.

Comparisons were made of a driven rod, 3/4" X 10' copperweld (8-20), a concrete encapsulated 3/4" X 10' copperweld rod (same as driven), one footing with anchor bolt not welded to rebar (35-200 for single bolts; 25-80 for two bolts in parallel); the welded rebar system described (9.5-19) and copper wire embedded in the footing (8-16).

Design of Shielded Cables Using Saturable Ferromagnetic Materials; David E. Merewether - IEEE Trans. on Electromagnetic Compatibility, Vol. EMC-12, No. 3, Aug. 1970, pp. 138-41.

Previously, a numerical solution was evolved that may be used to analyze the effect of material saturation on the low frequency shielding characteristics of a thin ferromagnetic cable shield. Numerical solutions are difficult to employ in design problems and so a simplified theory has also been developed. This supplemental theory, described here, yields simple equations useful in the design of ferromagnetic cable shields to provide protection against some anticipated intense low frequency environment.

Lightning Protection of Cable-Connected High-Voltage Distribution Substations by Surge Diverters; M. Ouyang - Proc. IEE, Vol. 117, No. 8, Aug. 1970, pp. 1693-1702.

For devising a general guideline on lightning protecting of distribution substations connected to overhead lines through cables, the surge voltages at both ends of the cable are derived for various types of incident lightning surges. The substation is represented by an open-circuited cable, which would result in surge voltages at the cable terminations equal to, or more severe than, the surge voltages for practical installations. The results are used to assess:

a. Whether protective devices are needed, b. when they are needed, whether surge diverters at one end of the cable provide adequate protection.

Attention is paid to the surge strength of the line insulation, as on it depend the types of incident lightning surge to be used in devising general guidelines.

<u>Behavior of Conductive Epoxy for Shielding and Bonding</u>; Alfred W. Dimarzio - Frequency Technology, Aug./Sept. 1970. pp. 18-23.

The application of conductive epoxies for interference control purposes is widespread. The performance of these epoxies is known only in general terms and is often clouded by use with other materials such as gaskets.

The investigation presented analyzes the epoxy as a means to bond covers onto compartmentized modules and afford intercompartmental shielding with no loss of packaging density due to fasteners. Secondly, the epoxy's bulk resistivity is analyzed versus frequency (0.15 to 60 MHz) and compared to other techniques used to achieve high frequency bonds. Lastly, a hypothesis is presented for optimum bond configuration and proposed application of a conductive epoxy.

The test sample was an epoxy-amine electrically conductive adhesive.

"A silver filled, two component, thermosetting resin system which when properly catalyzed and cured will produce an electrically conductive material for use as electrical contacts, terminations and adhesive."

<u>Bridge Method Simplifies Screening-factor Measurement</u>; A. Tomica - Electronic Engineering (London), Vol. 42, No. 511, Sept. 1970, pp. 76-8.

Measuring the screening factor on cable samples gives an indication of the protection from induced emf's offered by magnetic screening materials to signal-currying conductors. A bridge method for measuring the screening factor is presented.

<u>Measurement of the Resistance ofPhysically Large Earth Electrode Systems</u>; G. F. Tagg - Proc. IEE (London), Vol. 117, No. 11, pp. 2185-90, Nov. 1970.

A continuation of earlier papers (Proc. IEE, Vol 111, pp. 2118-30 and Vol. 116, pp. 475-479). In the earliest method, an auxiliary current electrode is placed at a distance from the ground system. In the Vol 116 method, shorter distances are permitted. Both earlier methods suffered by not permitting estimates of system departure from assumptions of soil homogenity. The Vol. 117 method requires a set of

18 measurements, from which by use of tables the resistance of the ground system is determined.

Cables and Connectors: A Compilation; NASA-SP-5936(01), 1971, N71-32371.

This report is a result of the Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear fields. This compilation covers a selected group of devices that have been developed to fulfill those cable and connector requirements that could not be satisfied by use of existing hardware.

The Control of Low Frequency Magnetically Coupled Power Line Interference; M G. Bates; R. Townsend, - IEEE Int. EMC Symposium Rec., 1971, pp. 288-93.

The development of a ground current isolator or common-mode choke is described within the context of an actual interference situation. Performance curves for experimental isolators are given a method for evaluating those power distribution system parameters pertinent to isolator performance is described.

The Use of Ionization in the Air for Lightning Protection; G. Berio - Isotopes and Radiation Technology, Vol. 8, No. 2, Winter 1970-71, pp. 178-179.

The E.F. (electricite froide) lightning rod, which uses eight ^{241}Am sources to promote the ionization of air is described. This rod has an effective radius of 250 m and is being used extensively in Europe to protect commercial installations from lightning.

Monte Carlo Determination of the Frequency of Lightning Strokes and Shielding Failures on Transmission Lines; J. R. Curpie, Liew Ah Choy, M. Darveniza - IEEE Trans. on Power App. Systems, Vol. 90, 1971, pp. 2305-2312.

The probabilistic approach of the Monte Carlo method has been applied to the electro-geometric model used for the analysis of frequency of lightning strokes and shielding failures on overhead lines. This approach has enabled theoretical studies to be made of how these

parameters are influenced by conductor sag, variations in terrain, and the presence of trees surrounding the line route.

We consider that the results given in this paper are only preliminary in nature and the predictions have yet to be validated by comparison with field data. Our principal objectives are to demonstrate the increased capability provided by the Monte Carlo method, and to offer preliminary results which will stimulate discussion and attract relevant field data from interested utilities.

Welded Joint and Termination for Aluminum Power Cables; Yoshio Hamada, Kazuo Tomita, Tsutomu Ishioroshi, Yasuhiko Miyake - Hitachi Rev., Vol. 20, No. 11, 1971, pp. 465-71.

In the past, compression joints or aluminum brazing joints were adopted for aluminum power cables; however, they involved problems concerning the joint dimensions as well as the actual jointing operations. To remedy this situation, the authors conducted research on cable joints by MIG-welding and obtained satisfactory results. We are already applying MIG-welding to cable terminals of 2,000 mm² and other sizes. Described here are the construction and welding method of aluminum welded joints, various test results on the welded joints, and their inspection methods.

Arrester Protection of High Voltage DC Transmission System Converter Terminals; J. S. Kresge, E. C. Sakshaug - IEEE Trans. Power App. System, Vol. 90, 1971, pp. 1555-62.

The specification, design, and testing of arresters for the HVDC Pacific Coast Intertie are discussed. Included in the report is a description of the overvoltage events significant to arrester design and the resulting specification. The basic problems associated with the arrester design and techniques used to overcome these problems are covered.

Propagation of Industrial Interference Over Actual Ground at 400 to 1000 MHZ; Enrico Paolini - IEEE Int. EMC Symposium Rec., 1971, pp. 118-21.

The propagation of interference over actual ground is modeled and can be used to predict its field by using test data attained on a specified test range. It will be shown that interferences generated by industrial sources and received by an antenna (both placed near the ground) propagate entirely along an earth path whereas useful radio transmission propagate largely along a free space path.

The value of the received interference field is a result of multiple random reflections and diffractions caused by all obstacles existing over a real earth. Therefore, it is possible to statistically establish an average attentuation law with values having a large standard deviation

As expected, the attenuation coefficients in the UHF range are larger than those published for lower frequencies. The loss of polarization, the lack of cancellation effects and the independence of path attenuation versus the height of the receiving antenna are evaluated and discussed.

<u>Study of Counterpoises in Poorly Conducting Soil</u>; E. Ya. Ryabkova, V. Z. Annenkov - Electric Technology, USSR, Vol. 2, pp. 133-143, 1971.

In soils having resistivity in the range 5-20 K -177, "solid" counterpoises afford good lightning protection, as noted on a 110 KV power transmission system.

The method of approach is different from those found in U.S. papers (Dwight, for exmaple, the Russian model for an earthing system is a transmission line with parameters that vary with distance from the ground point(s). Impulse response can thus be analyzed as a digitized time sequence of earthing parameter values, which are different at each computation time.

<u>Current Limiting Gap Arresters - Some Fundamental Considerations</u>; E. C. Sakshaug - IEEE Trans. Power App. Sys., Vol. 90, 1971, pp. 1563-73.

Current limiting gap arresters can be designed to operate successfully against swtiching surges and sustained overvoltages, but the current drawn by the arrester and the energy dissipated is a function of the circuit impedance as well as the system voltage and arrester design. Arresters designed to operate against sustained overvoltages may produce sufficient discharge voltage during operation to exceed arrester sparkover voltage and thus not provide the protection expected. A test method is suggested to determine the maximum voltage that an arrester may produce under normal operating conditions.

<u>Transient Response Characteristics of Capacitive Potential Devices</u>; Andrew Sweetana - IEEE Transactions on Power App. Sys., Vol. 90, 1971, pp. 1989-2001.

Full voltage line to ground fault tests are performed on typical potential devices and the subsidence transient recorded. To show the worst case of residual voltage, faults are initiated while the primary voltage is passing through crest and zero.

Thevenin's equivalent circuit tests using the actual, not model, components operating at rated tap voltage, are shown to agree with the full voltage tests. A mathematical analysis solved by computer, also concurs with the full voltage and equivalent circuit results.

Eight parameters which affect the transient response of capacitive potential devices are identified and analyzed. Finally, suggestions are made as to how this information can be utilized by the protective relay users and manufacturers.

<u>Corrosion Control Aspects of Underground Residential Electrical Distribution Systems</u>; Materials Protection and Performance, Vol. 10, No. 1, Jan. 1971, pp. 38-40.

This report acquaints interested individuals and companies with the wide diversity of ideas and practices that are being used for corrosion prevention and control on underground electric distribution systems for rural or low density areas.

<u>Service Experience With Lightning Arresters Under Contaminated Conditions</u>; IEEE Trans. on Power App. and Sys., Vol. PAS-90, No. 1, Jan/Feb. 1971, pp. 369-83.

The Working Group on Lightning Arrester Contamination Performance and Durability of the Overvoltage Protective Devices Subcommittee of the IEEE Surge Protective Devices Committee has prepared a final report summarizing the replies to a questionnaire on arrester serviceability under contaminated conditions. The questionnaire was distributed in 1966 by members of the working group to electric utility companies throughout the United States. An evaluation of the responses is presented in this paper, and several significant observations are made and conclusions reached. A variety of contaminants which might affect arresters is described in addition to the extent to which preventative practices and procedures are utilized to minimize the effects of contamination on arresters. A distinction is made between station or intermediate class arresters and distribution class arresters concerning the possible processes contributing to failure from contamination.

Electric Shocks and Safety Earthing; K. S. Kuka - J. Inst. Eng. (India), Elec. Engrg. Div., Vol. 51, No. 6, Pt. EL, Feb. 1971, pp. 140-54.

This paper discusses the basic features of safety earthing so that the earthing practice could be rationalized based on the understanding of the problems involved. The nature of the danger of electric shocks to human beings, development and measurement of shock voltages, method of designing system grounding stations, conditions of establishing high voltage and low voltage neutral grounding stations, nature of the fault currents through the earth and other important aspects of the problems created by ground faults on electrical systems are discussed.

Determining Salinity in Field Soils and Soil Resistance Measurements; J. D. Rhoades B. D. Ingralson - Soil Sci. Soc. Amer. Proc. Vol. 35, No. 1, pp. 54-60, Jan./Feb. 1971.

An instrument for use by agricultural scientists is described. "Electrical conduction in saline soils is primarily electrlytic" for a given soil type we should be able to correlate soil conductivity with soil salinity, especially if such measurements are made at a constant water content. Soil resistance measurements were made with a Model 63220 Megger Null Balance Earth Tester on plots of varying salinity, which had been saturated with water. The data was then processed to conform with those models and the resultant conductivities were compared with laboratory measures of conductivity of saturation soil extracts (a standard way to determine soil salinity). Correlation and regression analysis showed good agreement for two models.

Surface Transfer Impedance and Cable Shielding Design; R. J. Oakley - Wire Journal, Vol. 4, No. 3, Mar. 1971, pp. 44-7.

Signals transmitted by cables are subject to distortions caused by disturbances outside the cables. These distortions can be reduced by appropriate shielding, but satisfactory protection varies widely in style and cost. Experimental verification of shielding effectiveness has long been a debated question and is the subject of this article.

The value of the surface transfer impedance of a shield can be shown to be a measure of its shielding effectiveness.

The results of surface transfer impedance measurements given here cover both the general and the particular types of shield and are valid up to 300 MHz.

The definition as used in this article is as follows:

If a current is caused to flow along the shield (all conducting layers, where more than one exist) of a coaxial cable, with its return path outside that coaxial cable, then the longitudinal voltage along an incremental length which results on the inside surface of the shield is related to that current by the surface transfer impedance; and has units of impedance per unit length.

Because the tolerable noise arriving at the end of the cable is often specified, different incident field intensities require different minimum shielding efficiencies. The engineer is limited in his choice of materials for shielding purposes by several factors including, (a) economic production of long lengths of cable, (b) installation and splicing requirements, and (c) the necessary avoidance of corrosion conditions.

On the other hand, the requirements of a good shield are many and the combinations of materials which yield them are even greater. Each combination has its limitations and advantages. What are they? How are they determined? Because calculations are very rare possibilities, and experience and estimation are unreliable, experimentation remains the only way of proving a shield.

<u>High Voltage Lightning Grounding Device</u>; NASA Tech. Brief, Lewis Research Center, Brief 71-10136, May, 1971.

This very brief paper presents the ckt diagram of a transient grounding device for the prevention of lightning-induced high voltage transients from reaching the inputs or outputs of solid-state systems.

<u>Digital Programme for the Calculation of Earthing Systems Using Concentric Rings</u>; A. W. D. Adama, A. P. Lintott - De INGENIEUR (Hague), Vol. 83, No. 20, pp. E 51-56, May 21, 1971.

Single and multiple concentric earthing ring system resistance computing algorithms are developed. The program is not included, but its source location is given. Program is Fortran IV, IBM 1130.

<u>Quick Cable Splices</u>; D. D. Rodger - Mining Congress Journal, Vol. 57, May, 1971, pp. 38-46.

A system for making permanent splices on damaged electrical trailing cable without having to remove the cable from the machine has been developed for coal industry use. Incorporating heat-shrinkable

components, the system involves cable preparation, joining conductors and heating.

The Effects of High-Voltage AC-Transmission Lines on Buried Pipelines; A. W. Peabody, Adrian L. Verhiel - IEEE Trans. on Ind. and Gen. Appl., Vol. IGA-7, No. 3, May/June 1971, pp. 395-402.

Electrical interference problems will result on pipelines laid in joint use rights-of-way or laid in close proximity with overhead ac transmission lines or substation facilities. Some of the interference problems are discussed and practical solutions are given on how to minimize or nullify the effects.

Bonding, Grounding, and Electrical Requirements for Electromagnetic Compatibility; Space and Missile Test Center Manual, SAMTEC, Manual 80-3, May 1, 1971.

This document establishes the minimum requirements for bonding and grounding of facilities and equipment and for technical power installation at SAMTEC. It is intended for use by design organizations specifying bonding and grounding requirements for new stallations, and by operating organizations having maintenance responsibility for new and existing installations. The application of this document in the construction of new facilities and equipment and the modification of existing facilities will insure the protection of personnel against the hazards of shock, fire, and explosion and will minimize Electromagnetic Interference (EMI) problems caused by incorrect bonding and grounding of electrical and electronic installations. This document contains criteria obtained from the NASA Standard KSC-STD-E-0012 dated December 29, 1969, and Philco-Ford WDL Division Report WDL-TR4201 dated 30 June 1970, plus criteria specifically oriented to SAMTEC, Vandenberg AFB, California.

This document does not cover bonding, grounding and electrical requirements peculiar to ships, aircraft, and missiles and is limited to the ground support of aerospace systems. However, for the convenience of the users of this document, the standards for ships and aerospace systems are listed in attachment 1. The requirements for systems processing classified information are not included in this document but can be obtained from the TEMPEST documents listed in Chapter 2. In order to accomplish its objective, this document necessarily delves to some extent into electrical/ electronic systems and equipment design practices. Such practices are covered only to the extent that they influence the overall bonding and grounding philosophy. Generally, additional bonding and grounding internal to the system or equipment may be required in order for the system or equipment to perform its intended

function. Complete coverage of such internal bonding and grounding requirements is beyond the scope of this document, and the determination of such requirements is the responsibility of system designers. Specific limitations in coverage of subjects mentioned, but not completely covered in this standard, are given.

<u>Switching Surge Duty on Modern Arresters</u>; E. R. Taylor, Jr., S. M. Merry - IEEE Trans. Power App. Sys., Vol. PAS-90, No. 3, May/June, 1971, pp. 1103-11.

This paper presents the results of an Anacom study which investigated the performance of modern lightning arresters during switching surge operation. A description of the variable characteristic arrester model used to simulate the lightning arrester is presented as are the results of the study using the model on a representative 345-kV system. Particular emphasis is placed on the parameters effecting the discharge current, voltages and energy with attention given to the protective characteristic of the arrester.

<u>On Calculating Transient EM-Fields of a Small Current-Carrying Loop Over a Homogeneous Earth</u>; James R. Wait, Randolph H. Ott - Institute for Telecommunications Sciences, U.S. Department of Commerce, Prepared for Air Force Research Labs., Contract No. PRO-Y-71-872, Scientific Report No. 53, July 14, 1971.

The basic theory of airborne EM surveying, in the time domain, is considered. Rather than resorting to tedious double numerical integration, a more direct approach is adopted. This method, valid in the quasi-static regime, is illustrated for a homogeneous flat earth. The results exhibit a number of clear-cut features that are relevant to remote sensing. (The results are basic to a proper understanding of airborne EM geophysical surveys).

<u>Electronic Monitor Guards Machine, Cables</u>; Coal Age, Vol. 76, Aug. 1971, pp. 70-1.

Bethlehem Mines Corp.'s Idamay No. 44 mine at Idamay, W. Virginia enhances safety on DC face equipment with a device which provides machines and trailing cables with ground-fault and short-circuit protection. The Lectronic Sentry, supplied by Joy Mfg. Co., has been in use for about 10 yr. at Idamay No. 44 and has significantly reduced the number of fires on machines and in cables.

The mine started using a prototype Sentry in 1961, but the unit has been revamped since then, and 26 continuous miners and shuttle cars now are equipped with protective devices. Machines include three Wabco 400, three Lee-Norse 48H and one Lee-Norse 48Y continuous miners, and 19 Joy 10SC shuttle cars. All equipment operates at 250 v dc.

Udder Disaster; Reprinted from "Small Business is our Business," Laboratories Highlights, Vol. 19, No. 3, Aug. 1971, The Franklin Institute Research Laboratories, Philadelphia, Pennsylvania .

This brief, amusing item is thought-provoking in citing a vivid outcome of using building plumbing for telephone line grounding. In the case cited, the plumbing was intentionally "isolated" electrically to alleviate corrosion problems, but so doing led to raising the plumbing electrically off the ground by virtue of the telephone ground connection to the plumbing. Results: stubborn milk-givers and dead cows.

Introduction to Lightning and Other Electrostatic Phenomena; Nixon A. Adams - Air Weather Service, Scott AFB, Illinois, Aug. 1971, AWS-TR-1

224.

The technicql report points out the importance of forecasters in the field understanding the basic physical principles of the lightning stroke, the lightning flash, and certain other electrostatic phenomena. Several varied theories on the creation of negative and positive charge centers in cumulo-nimbus clouds are presented by the author for the readers consideration. The integral parts of a single lightning flash are covered in detail and the author furnishes a better insight to the lightning phenomenon than normally held by the weather forecastors in the field.

Surface Transfer Impedance of Cable Shields Having a Longitudinal Seam; David E. Griffith - IEEE Trans. of Communication Technology, Vol. COM-19, No. 4, Aug. 1971, pp. 517-22.

The magnitude of noise induced into communication cable from electromagnetic influences is reduced by the shielding properties of the metallic shield. One of these properties is the surface transfer impedance. The surface transfer impedance relates the current induced on one side of a shield to the longitudinal voltage appearing on the other side due to that current. At low frequencies the surface transfer impedance for nonpermeable materials is equal to the dc resistance of the shield. At high frequencies it decreases rapidly. The frequency at which the decrease begins is a function of the thickness and

conductivity of the metal. For cylindrical shields having longitudinal seams, the transfer impedance increases at somewhat higher frequencies. The size of the seam opening determines the frequency at which the increase begins. Although the size of the seam opening is difficult to control, experimental results are in relatively good agreement with theoretical claculations.

<u>Cable Shielding Innovations Promise Greater Reliability</u>; N. Peach - Power, Vol. 115, Sept. 1971, pp. 94-5.

Spiral-taped shields may be damaged when carrying ground fault current. The article presents new designs to tackle this and other problems.

<u>VHF/UHF Ground-Air-Ground Communications Siting Criteria</u>; James G. Dong - National Aviation Facilities Experiment Station, Atlantic City, New Jersey, Final Report, FAA-RD-71-76, Prepared for Department of Transportation, FAA, Systems Research and Development Service, Nov. 1971.

The report presents results of tests accomplished at the NAFEC and selected FAA field facilities to determine RF communication problems and equipment performance Remote Transmitter Receiver (RTR) and Remote Center Air-Ground(RCAG) configuration. Performance characteristics of antennas, transmitters, receivers, transmission lines, and ancillary equipment were investigated to determine the parameters that affect mutual interference when these equipments are combined in FAA system configurations. The results of the investigation were limited to equipment in current use at field sites and equipment recently developed. Data are incorporated in Appendix A of the report for use as a field manual. The field manual was prepared to provide reference and guidance to installation and maintenance personnel on interference aspects in correcting similar problems at existing sites and the application of these principles in establishing new sites.